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Marine Mammal Acoustic Effect Modeling Conducted for the Undersea Warfare Training Range Preferred Site at Onslow Bay

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NEWPORT

Naval Undersea Warfare Center Division Newport, Rhode Island

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PREFACE

This report was prepared under NUWC Division Newport Project No. A744015, the program manager is Steven D. Jette (Code 701). The sponsoring activity is the Naval Air Systems Command (PMA-205).

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The Undersea Warfare Training Range is a proposed training range with candidate sites in waters off the coast of Virginia, North Carolina, and Florida. Construction of the range requires an approved Environmental Impact Statement. This report describes the modeling approach, inputs, and analysis results of the Marine Mammal Acoustic Effects Model that was developed in support of the Undersea Warfare Training Range to estimate the training range acoustic effects on mammals in the candidate sites.

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EXECUTIVE SUMMARY

The U.S. Navy is preparing a Draft Environmental Impact Statement/Overseas Environmental Impact Statement (DEIS/OEIS) for the proposed Undersea Warfare Training Range (USWTR). The DEIS includes an assessment of effects of Navy sonars on marine mammals during exercises to occur on the range as required by the Marine Mammal Protection Act (MMPA). The Naval Undersea Warfare Center (NUWC) Division, Newport, RI, has completed this assessment for three sites: the preferred site of Onslow Bay, NC, and the alternate sites of Wallops Island, VA, and Jacksonville, FL. This document describes the input data and the analysis method employed to estimate the number of marine mammals that could be affected by operation of Navy tactical sonar systems at the USWTR.

Site naming conventions were revised in August 2005 for clarification; however, the former range naming conventions are used in this report. It should be noted that the DEIS/OEIS Site A is referred to here as “Onslow Bay,” Site B is referred to as “Wallops Island,” and Site C is referred to as “Jacksonville”.

The input data, which are key to this methodology, fall into five categories:

- Navy Training Requirements,
- Acoustic Source Data,
- Acoustic Environment,
- Marine Mammal Populations, and
- Acoustic Effect Definitions.

The training scenarios were generated with guidance from the Navy to capture the scope and volume of training planned on a yearly basis. The source operational characteristics were collated by NUWC Division Newport from numerous sources, including Atlantic and Pacific Fleet commands, systems operating guidelines, and technical design documentation. Geophysical data were compiled by NUWC Division Newport from multiple sources, primarily National Oceanographic and Atmospheric Administration (NOAA) databases. Information on marine mammal density estimates is a summary obtained from several Department of the Navy documents (2002a, 2002b, and 2002c). A Navy panel convened by the Chief of Naval Operations Environmental Readiness Division (CNO N45) defined the marine mammal harassment criteria used (Level A and Level B harassment thresholds). The USWTR DEIS explains Level A and Level B sonar criteria, thresholds for cetaceans, and how they were derived

The methodology employed calculates the area within which each source produces a total energy flux above the acceptable defined Level A and Level B harassment thresholds. This area is multiplied by the mammal population densities for each species and the number of scenario occurrences per year to determine the annual estimate of takes. Calculations based on harassment thresholds are performed for each combination of training scenario, source and season with results summarized by sonar system, scenarios, and species.

The final estimated number of takes depends on the input data values for each of the parameters. Each category has a varying degree of confidence and stability with time. For example, the Onslow Bay mammal density estimates depend on sparse data. Conversely, the yearly training activity is precisely quantified. The goal was an unbiased prediction of the number of takes that are expected over the duration of one year's training given these diverse and variable factors. Average or typical values were emphasized. The estimates do not represent an absolute guarantee of the interaction of sound and mammals on a day-to-day or annual basis.

The estimated annual takes for Level B harassment at Onslow Bay, Wallops Island, and Jacksonville were 999, 1207, and 562, respectively. At all sites the surface ship sonars attributed to greater than 85% of the annual total, with the AN/SQS-53 vastly dominating. The balance of takes was due to the operation of torpedo, helicopter dipping, and submarine sonars. Level A harassment was estimated to be 1 at each site. Level A harassment is thought unlikely due to the small harassment areas, nearfield effects in proximity to the larger sonar, and minimal results overall. This is further emphasized when combined with standard operating procedures to avoid ship strikes of mammals, which simultaneously mitigate Level A harassment.

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LIST OF ABBREVIATIONS AND ACRONYMS

ADCAP	Advanced capability
ADC	Acoustic device countermeasure
AE	Acoustic energy
AHA	Acoustic hemispherical array
ALFS	Airborne low-frequency sonar
ALW	Advanced capability lightweight
APL/UW	Applied Physics Laboratory/University of Washington
ASW	Antisubmarine warfare
CASS	Comprehensive Acoustic System Simulation
CM	Countermeasure
CNO	Chief of Naval Operations
COMPTUEX	Composite Training Unit Exercise
CW	Continuous waveform
dB	Decibel
DEIS	Draft Environmental Impact Statement
DICASS	Directional Command Active Sonobuoy System
EIS	Environmental Impact Statement
EL	Energy level
EMATT	Expendable Mobile ASW Training Target
EXTORP	Exercise torpedo
FM	Frequency modulation
fm	Fathom
HA	High-frequency array
HF	High frequency
INDEX	Independent Deployer Exercise
JTFEX	Joint Task Force Exercise
km	Kilometer
LAMPS	Light Airborne Multipurpose System
LFBA	Low-frequency bow array
LFBLTAB	Low-Frequency Bottom-Loss Model
LSA	Large spherical array
m	Meter
MF	Mid Frequency
MGS	Marine Geophysical Survey
MIDAS	Mine Ice Detection and Avoidance System
MMPA	Marine Mammal Protection Act
NDBC	National Data Buoy Center
nmi	Nautical mile
NOAA	National Oceanographic Atmospheric Administration
NODC	National Oceanographic Data Center

LIST OF ABBREVIATIONS AND ACRONYMS (Cont'd)

NUWC	Naval Undersea Warfare Center
OAML	Oceanographic and Atmospheric Master Library
OEIS	Overseas Environmental Impact Statement
OPAREA	Operational area
Pa	Pascal
PTS	Permanent threshold shift
REXTORP	Recoverable exercise torpedo
RMS	Remote Mine Hunting System
SADS	Submarine Active Detection Sonar
Sonar	Sound navigation and ranging
SPAWAR	Space and Naval Warfare Systems Center
SPL	Sound pressure level
SSP	Sound speed profile
SWTR	Shallow Water Training Range
TTS	Temporary threshold shift
UQC	Underwater communications
USWTR	Undersea Warfare Training Range
UUV	Unmanned underwater vehicle
VACAPES	Virginia Capes
WAA	Wide aperture array

MARINE MAMMAL ACOUSTIC EFFECT MODELING CONDUCTED FOR THE UNDERSEA WARFARE TRAINING RANGE PREFERRED SITE AT ONSLOW BAY

1. INTRODUCTION

The U.S. Navy is preparing a Draft Environmental Impact Statement/Overseas Environmental Impact Statement (DEIS/OEIS) for the proposed Undersea Warfare Training Range (USWTR), which includes assessment of effects of Navy sonars on marine mammals during planned exercises on the range. The site naming conventions were revised in August 2005 for clarification. The former range naming conventions are used in this report. It should be noted that DEIS/OEIS Site A is referred to in this report as “Onslow Bay,” Site B is referred to here as “Wallops Island,” and Site C is referred to as “Jacksonville.”

The Naval Undersea Warfare Center Division, Newport, RI, has completed prediction of the interaction of the military sonars with marine mammals at the preferred Onslow Bay site and at the alternate sites of Wallops Island and Jacksonville. As part of the Environmental Impact Statement (EIS) process and the Marine Mammal Protection Act (MMPA), the Navy is required to assess effects of sonar operations in a quantitative manner and to estimate the numbers of marine mammals that could be affected by these activities. This document describes the input data used and the analysis method employed to estimate the number of marine mammals that could be affected by operation of Navy tactical sonar systems at USWTR.

The input data, which are key to this methodology, fall into five categories:

- Marine mammal density estimates for the proposed range locations,
- Definitions for Level A and Level B harassment thresholds for Navy sonar systems,
- Geophysical data for the sites,
- Characterization of Navy training scenarios and the military sonars to be used, and,
- Operational characteristics for the sonar systems to be used (many of these parameters are classified).

Information on marine mammal density estimates was obtained from several Department of the Navy documents (2002a, 2002b, 2002c). Geophysical data were compiled by NUWC Division Newport from multiple sources. A Navy panel convened by the Chief of Naval Operations Environmental Readiness Division (CNO N45) established the definitions used for the marine mammal harassment criteria, Level A and Level B harassment thresholds. The USWTR DEIS explains Level A and Level B sonar criteria and thresholds for cetaceans and how they were derived.

The training scenarios were defined by the Navy to capture the full scope of activities expected at the range on a yearly basis. Lastly, the operational characteristics data were collated by NUWC Division Newport from numerous sources, including the Atlantic and Pacific Fleet commands, systems' operating guidelines, and technical design documentation. All unclassified input data are summarized in this document.

This report describes how the analysis was conducted. The model calculates an area for which each source produces a total energy flux (also referred to as total acoustic energy or total energy flux density) above the defined Level A and Level B harassment thresholds. This is calculated for each combination of training scenario, source, and season. This area is multiplied by the mammal population density for each species and the number of scenario occurrences per year to determine the estimated number of takes that will occur annually. Data are summarized by harassment thresholds for the respective sonar system, scenario, and species. A summary of the input data for the methodology is provided in figure 1-1, and a flow chart for the modeling shown in figure 1-2.

The final results are described as the "estimated number of takes." These results depend on the input data values for each of the categories described above. Each category has a varying degree of confidence and stability with time. The results also depend on definitions made for the methodology which bound the volume of analysis. Without these constraints, the number of variations that could be modeled would be near infinite. The use of defined ship tracks, specific acoustic propagation analysis points, representative training scenarios and typical source characteristics are all examples of this point. The goal was an unbiased prediction of the number of takes that are expected over the duration of one year's training given these diverse and variable factors. It does not represent an absolute guarantee of the interaction of sound and mammals on a day to day or annual basis since variations can occur relative to the modeled parameters. Instead, the results represent the average that would be expected.

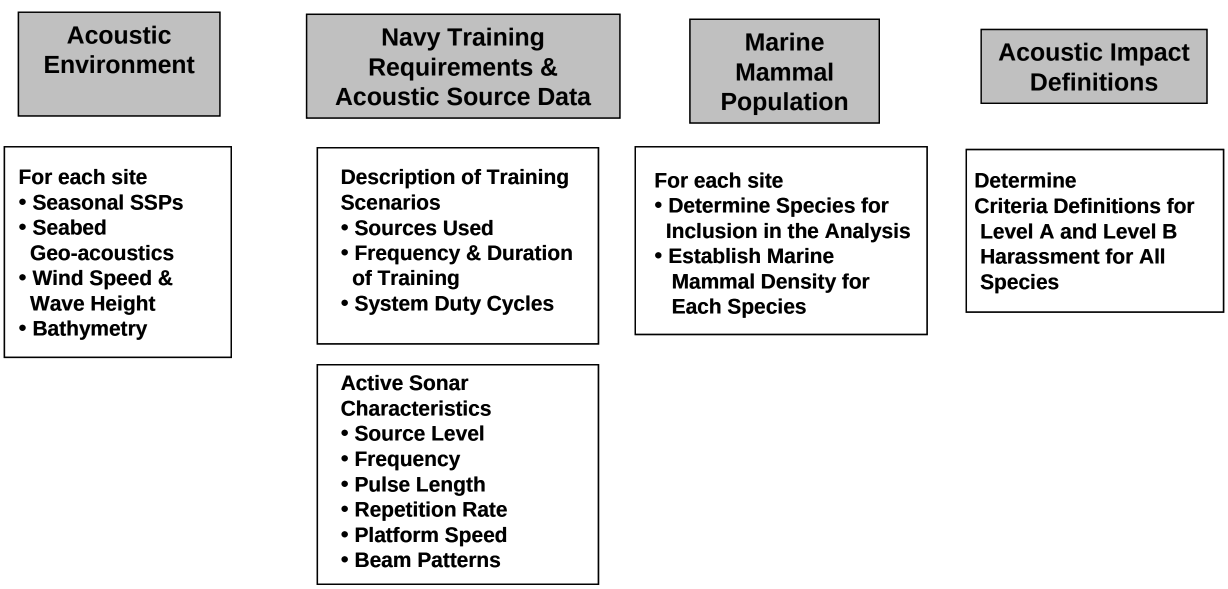

Figure 1-1. Summary of Analysis Input Data

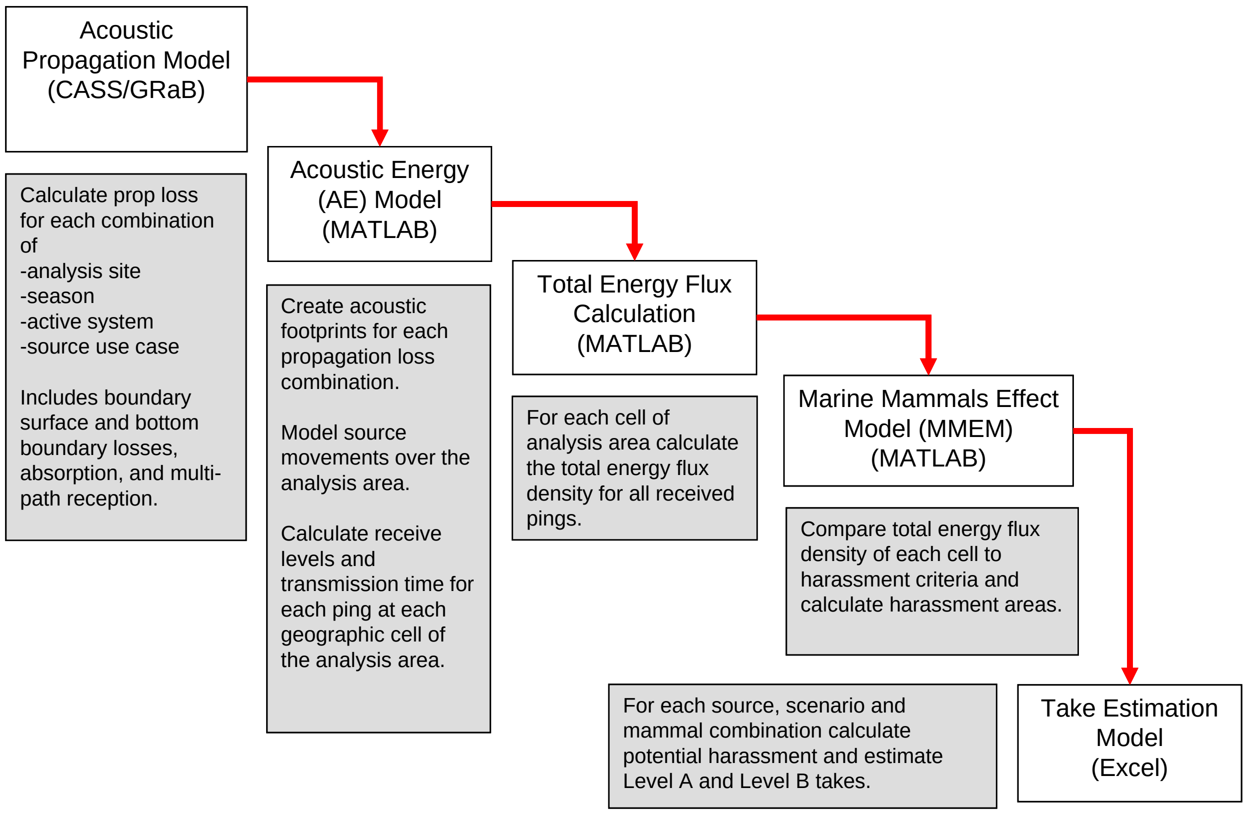

Figure 1-2. Summary of Modeling Steps, Models, and Software Platforms

2. DISTRIBUTION AND ABUNDANCE OF MARINE MAMMALS AT THE PROPOSED USWTR LOCATIONS

One important aspect in the evaluation of potential effects to marine mammals in any given area is a thorough understanding of the distribution and abundance of the mammals within that geographic area. For the USWTR, this understanding was derived through examination of existing data and is generally supported by relevant literature. For purposes of modeling, quantification of the distribution and abundance were achieved by evaluation of the spatial and temporal distributions and the abundance of marine mammals throughout the three regions that included the proposed USWTR locations. The following information was obtained from the Department of the Navy (2002a, 2002b, 2002c), Hain (2004, 2005a), and Hain and Kenney (2001). All marine mammal nomenclature used was consistent with Rice (1998) and Perrin and Brownell (2001).

2.1 OVERVIEW

The oceanographic conditions for all proposed sites are very different and, subsequently, the marine mammal fauna differs accordingly. Data indicated that only cetaceans (whales) are regularly distributed in the range areas, while other marine mammals (e.g., seals), if encountered in or around the proposed locations, were considered strays or vagrants. Also, the cetacean fauna offshore of Wallops Island was found to be more diverse, and the area appears to support a greater number of cetaceans than the areas offshore of Onslow Bay and Jacksonville.

Cetacean fauna was characterized for the model using all available marine mammal survey and sighting data for all locations. The complete list of documented species found in the vicinity of Cape Hatteras and Jacksonville was developed and then sorted for those that can reasonably be expected to occur within and nearby the proposed range locations.

Characterization of the distribution and abundance of marine mammals was accomplished quantitatively by calculating estimates of the number of each species that may be expected within the region. The resultant density estimates were stratified by depth to further represent distributions and relative concentrations of species within the regions. The stratified density estimates were then used as inputs to the acoustic effect modeling process.

2.1.1 Data Quality

Both quantity and quality of available marine mammal survey data differed between locations; therefore, the strength of the results and confidence in the density estimates for the three locations also varied. Available data for the Virginia-Capes Operations Area (VACAPES OPAREA) area, including the proposed alternate location offshore of Wallops Island, VA, were found to be generally robust as the area has a good history of study (e.g., CeTAP 1982, aerial surveys for shock trials of *Seawolf* and *Winston S. Churchill*). Available data for the Cherry Point

Operations Area (OPAREA), including the proposed location offshore of Onslow Bay, NC, were patchy, leaving many areas undersampled (e.g., offshore beyond the shelf break). As a result, the density estimates presented for Onslow Bay may be somewhat speculative, and those for Wallops Island are considered satisfactory and representative. The data available for the shoreward area of Jacksonville were representative, but the data offshore had sparse data coverage.

2.1.2 Dive-Time Correction

For species that spend a large proportion of their time submerged, surveys from fast moving platforms will miss many individuals or groups while they are below the surface. Dive-time correction factors have been derived from data on the relative proportions of time that an animal spends at the surface and submerged and have been applied by a number of investigators to present more realistic estimates of abundance (e.g., Kenney, 1997). Density estimates, used here as inputs to the model, include available dive-time corrections. Generally, dive-time corrections were available for deep-diving cetaceans, such as large whales and beaked whales, but were not available for small cetaceans, such as dolphins and porpoises.

2.1.3 Unidentified Cetaceans

Unidentified sightings, i.e., those of mammals where identification to a species was not possible, frequently compose the largest sighting category. These sighting categories can amount to 25% or greater of a total sightings, but have no standard grouping across the various available data. Because there are no standards for recording unidentified or partially identified sightings, there was no way to uniformly consider these categories across the data sets for estimation of density. As a result, one can reasonably assume that the density estimates used for modeling potential acoustic effects are underestimates and are approximately in proportion to the sighting frequency of identified species. Often, cryptic species and those that are difficult to identify will make up a disproportionate percentage of the unidentified sightings and will be negatively biased. To account for this bias, the model results were increased by the proportion of unidentified sightings found in all the data used to calculate the density estimates at each location (Department of the Navy, 2002). Therefore, the adjusted harassment estimates are more likely to be representative.

For the Onslow Bay region, unidentified dolphins and *stenella* comprised 24.4% of all dolphins sighted. Unidentified medium and large whales comprised 14.8% of all whales sighted. Therefore, increasing the estimated densities of identified species of dolphins and *stenella* by 32.2% and increasing the densities of identified species of medium and large whales by 17.4%, redistributed the sightings of unidentified marine mammals proportionately across similar identified species. Thus,

$$\%\,\textit{increase to known species} = \left[\frac{\textit{total number (identified and unidentified)}}{\textit{(number of identified)}} - 1\right] * 100.$$

For the VACAPES region, unidentified dolphins and *stenella* comprised 34.7% of all dolphins sighted; and unidentified medium and large whales comprised 32.1% of all whales sighted. The density estimates for identified dolphins and *stenella* and identified medium and large whales were increased by 53.2% and 47.3%, respectively. For the Jacksonville region, unidentified dolphins and *stenella* comprised 11.3% of all dolphins and *stenella*; and unidentified medium and large whales comprised 1.96% of all whales sighted. The density estimates for identified dolphins and *stenella* and identified medium and large whales were increased by 12.8 % and 2.0 %, respectively.

Densities of marine mammals for the candidate sites are contained in tables 2-1 through 2-6. These densities do not reflect adjustments for the unidentified species. The adjustments were made to the final take estimates.

Table 2-1. Marine Mammal Densities for the Onslow Bay Preferred Site (0-50 Fathoms)
(On-shelf depth zone (0-50 fathom (0-91.4 m)) density estimates per nmi^2 (per 1000 km^2) for the Cherry Point OPAREA Region.)

Species	Winter	Spring	Summer	Fall
Mysticetes				
Fin Whale	0.000	0.000	0.000	0.000
Humpback Whale	7.920	7.920	0.000	0.000
North Atlantic Right Whale*	0.875	0.875	0.000	0.875
Odontocetes				
Sperm Whale	0.000	0.000	0.000	0.000
Pygmy/Dwarf Sperm Whale	0.000	0.000	0.000	0.000
Killer Whale	0.000	0.000	0.000	0.000
False Killer Whale	0.000	0.000	0.000	0.000
Pilot Whale	0.000	0.000	0.000	0.000
Bottlenose Dolphin	165.300	8.230	65.590	19.980
Common (Saddleback) Dolphin	0.000	19.040	19.040	0.000
Risso's Dolphin (Grampus)	0.000	0.000	0.000	0.000
Rough-Toothed Dolphin	0.000	0.000	0.000	0.000
Spotted Dolphin	116.000	306.000	306.000	306.000
Striped Dolphin	0.000	0.000	0.000	0.000
Spinner Dolphin	0.000	0.000	0.000	0.000
Clymene Dolphin	0.000	0.000	0.000	0.000
Clymene Dolphin	0.000	0.000	0.000	0.000
Harbor Porpoise	0.000	0.000	0.000	0.000
Source DoN, 2002b. *Density for North Atlantic right whales is for the 20-50 fm depth regime for this species only (Hain, 2005b).				

Table 2-2. Marine Mammal Densities for the Onslow Bay Preferred Site (50-1100 Fathoms)
(On-shelf depth zone (>50 fathom (91.4m)) density estimates per nmi^2 (per 1000 m^2) for the Cherry Point OPAREA region.)

Species	Winter	Spring	Summer	Fall
Mysticetes				
Fin Whale	0.000	0.000	0.000	0.000
Humpback Whale	0.000	0.000	0.000	0.000
North Atlantic Right Whale	0.000	0.000	0.000	0.000
Odontocetes				
Sperm Whale*	27.980	0.000	8.060	0.000
Pygmy/Dwarf Sperm Whale	0.459	0.000	0.459	0.000
Killer Whale	0.000	0.000	0.000	0.000
False Killer Whale	0.000	0.000	0.000	0.000
Pilot Whale	8.800	8.800	6.550	8.800
Bottlenose Dolphin	46.930	19.600	22.740	47.500
Common (Saddleback) Dolphin	107.930	107.930	107.930	9.530
Risso’s Dolphin (Grampus)	17.000	10.250	17.000	17.000
Rough-Toothed Dolphin	0.000	0.000	1.040	0.000
Spotted Dolphin	116.000	116.000	92.530	116.000
Striped Dolphin	0.000	0.000	0.000	0.000
Spinner Dolphin	0.000	0.000	0.000	0.000
Clymene Dolphin	0.000	0.000	5.030	0.000
Clymene Dolphin	0.000	0.000	5.030	0.000
Harbor Porpoise	0.000	0.000	0.000	0.000

Source DoN, 2002b.
*Sperm whale density derived for entire Cherry Point OPAREA – species are not expected to occur at these densities at the site of USWTR.

Table 2-3. Marine Mammal Densities for the VACAPES Alternate Site (20-50 Fathoms)
(Marine mammal density estimates per nmi^2 (per 1000 km^2) at VACAPES in the mid-shelf stratum (20-50 fathoms (40-100 m)).)

Species	Winter	Spring	Summer	Fall
Mysticetes				
Blue Whale	0.00	0.00	0.00	0.00
Fin Whale	19.10	9.02	5.76	0.19
Sei Whale	0.76	0.00	0.23	0.01
Minkes Whale	0.00	0.65	1.91	0.00
Humpback Whale	0.76	0.00	0.23	0.00
North Atlantic Right Whale*	1.72	0.81	0.00	0.02
Odontocetes				
Sperm Whale	0.00	0.018	0.00	0.00
Pygmy/Dwarf Sperm Whale	0.00	0.00	0.00	0.00
All Beaked Whales	0.00	0.00	0.32	0.00
Killer Whale	0.00	0.00	0.00	0.00
Pygmy Killer Whale	0.00	0.00	0.00	0.00
Melon-Headed Whale	0.00	0.00	0.00	0.00
False Killer Whale	0.00	0.00	0.00	0.00
Pilot Whale	0.00	17.20	0.91	0.00
Bottlenose Dolphin	7.00	42.88	32.73	10.32
White-Beaked Dolphin	0.00	0.00	0.00	0.00
Atlantic White-Sided Dolphin	0.00	0.00	0.65	0.00
Fraser’s Dolphin	0.00	0.00	0.00	0.00
Common (Saddleback) Dolphin	312.38	110.75	8.07	235.30
Risso’s Dolphin	0.86	17.02	23.23	1.83
Rough-Toothed Dolphin	0.00	0.00	0.00	0.00
Spotted Dolphin	90.59	32.12	2.34	68.24
Striped Dolphin	0.00	0.00	0.00	16.00
Spinner Dolphin	0.00	0.00	0.00	0.00
Clymene Dolphin	0.00	0.00	0.00	0.00
Harbor Porpoise	13.13	13.13	0.00	0.00
Source: DoN 2002a and Hain 2005a. *Densities for North Atlantic right whale are seasonal average derived from Hain (2005a)				

Table 2-4. Marine Mammal Densities for the VACAPES Alternate Site (50-1100 Fathoms)
(Marine mammal density estimates per nmi^2 (per 1000 km^2) at VACAPES in the shelf-edge stratum (50-1100 fathoms (100-2200 meters)).)

Species	Winter	Spring	Summer	Fall
Mysticetes				
Fin Whale	7.89	25.30	8.45	4.51
Sei Whale	0.71	2.28	0.00	0.00
Minkes Whale	0.95	3.04	0.00	0.54
Humpback Whale	1.89	1.33	0.18	0.00
North Atlantic Right Whale*	0.24	0.76	0.00	0.00
Odontocetes				
Sperm Whale	27.98	22.75	8.06	6.91
Pygmy/Dwarf Sperm Whale	0.00	0.00	2.73	0.00
All Beaked Whales	0.00	10.75	2.40	0.00
Killer Whale	0.00	0.10	0.00	0.00
Pygmy Killer Whale	0.00	0.00	0.00	0.00
Melon-Headed Whale	0.00	0.00	0.00	0.00
False Killer Whale	0.00	0.00	0.55	0.00
Pilot Whales	0.00	33.23	54.67	178.59
Bottlenose Dolphin	45.74	85.98	93.52	126.41
White-beaked Dolphin	0.00	0.00	0.00	0.00
Atlantic White-Sided Dolphin	0.00	0.53	0.61	0.00
Fraser’s Dolphin	0.00	0.00	0.00	0.00
Common (Saddleback) Dolphin	309.47	132.93	43.55	352.26
Risso’s Dolphin	46.17	53.33	61.16	103.30
Rough-Toothed Dolphin	0.00	0.00	0.55	0.00
Spotted Dolphins	58.63	56.14	55.30	58.63
Striped Dolphin	57.07	35.54	1.33	0.00
Spinner Dolphin	1.14	0.71	0.00	0.00
Clymene Dolphin	0.00	0.00	0.00	0.00
Harbor Porpoise	13.13	0.00	0.00	0.00
Source: DoN 2002a and Hain 2005a. *Densities for North Atlantic right whale are from Hain (2005a).				

Table 2-5. Marine Mammal Densities for the Jacksonville Alternate Site (0-50 Fathoms)

(On-shelf depth zone (0-50 fathom (0-91.4m)) density estimates per nmi^2 (per 1000 km^2) for the Jacksonville OPAREA Region.)

Species	Winter	Spring	Summer	Fall
Mysticetes				
Fin Whale	0.000	0.000	0.000	0.000
Humpback Whale	0.480	0.480	0.000	0.480
Minke Whale	0.000	0.000	0.000	0.000
North Atlantic Right Whale*	1.240	0.41	0.000	0.000
Odontocetes				
Sperm Whale	0.000	0.000	0.000	0.000
Pygmy/Dwarf Sperm Whale	0.000	0.000	0.000	0.000
False Killer Whale	0.000	0.000	0.000	0.000
Pilot Whale	0.000	0.000	0.000	0.000
All Beaked Whales	0.000	0.000	0.000	0.000
Bottlenose Dolphin	181.900	8.160	46.320	20.110
Common (Saddleback) Dolphin	0.000	0.000	19.040	0.000
Rissos' Dolphin (Grampus)	0.000	0.000	0.000	0.000
Rough-Toothed Dolphin	0.000	0.000	0.000	0.000
Spotted Dolphin	169.100	306.000	306.000	306.000
Spinner Dolphin	0.000	0.000	0.000	0.000
Source DoN, 2002a, and Hain 2004. *Densities for North Atlantic right whale are from Hain (2004).				

Table 2-6. Marine Mammal Densities for the Jacksonville Alternate Site (50-1100 Fathoms)
(On-shelf depth zone (>50 fm (91.4 m) density estimates per nmi^2 (per 1000 km^2) for the Jacksonville OPAREA Region.)

Species	Winter	Spring	Summer	Fall
Mysticetes				
Fin Whale	0.000	0.000	0.000	0.000
Humpback Whale	0.000	0.000	0.000	0.000
Minke Whale	31.680	0.000	0.000	0.000
North Atlantic Right Whale*	0.000	0.000	0.000	0.000
Odontocetes				
Sperm Whale	0.000	0.000	0.000	0.000
Pygmy/Dwarf Sperm Whale	0.460	0.460	0.460	0.460
False Killer Whale	0.040	0.040	0.040	0.000
Pilot Whale	1.400	1.270	1.400	1.400
All Beaked Whales	42.240	42.240	3.540	42.240
Bottlenose Dolphin	0.000	28.570	27.690	47.500
Common (Saddleback) Dolphin	0.000	0.000	107.930	0.000
Rissos' Dolphin (Grampus)	15.650	15.390	15.650	15.650
Rough-Toothed Dolphin	0.020	0.020	0.020	0.000
Spotted Dolphin	18.030	14.180	18.030	18.030
Spinner Dolphin	0.000	4.090	4.090	0.000
Source DoN, 2002a, and Hain 2004. *Densities for North Atlantic right whale are from Hain (2004).				

2.1.4 Temporal Distribution

Training at the proposed locations may occur throughout the year. To account for seasonal variability in the temporal distribution of marine mammals, it was necessary to partition the year appropriately. Density estimation was calculated by seasons defined by astronomical conventions: winter (December 21 through March 20), spring (March 21 through June 20), summer (June 21 through September 20), and fall (September 21 through December 20).

2.1.5 Spatial Distribution

Distributions of marine mammals are frequently characterized by association with various depth strata and are closely linked to habitat use or resource exploitation. Because the USWTR straddles the shelf edge and includes adjacent waters, it was necessary to apply the density estimates according to how species were likely to occupy the regions. The USWTR and adjacent waters included two of four defined strata, mid-shelf and shelf-edge waters, and did not include nearshore and slope waters. The four strata are defined as follows:

Near shore waters	<20 fathoms (not included),
Mid-shelf waters	20-49 fathoms,
Shelf-edge waters	50-1099 fathoms, and
Slope waters	>1100 fathoms (not included).

2.1.6 Cautions

Density estimates where dive-time correction was not applied may represent minimum estimates of abundance. As a result, an estimate of harassment by a model using minimum estimates of abundance as inputs represents a minimum estimate. In general, dive-time corrections were not available for dolphin species so those categories will be affected.

2.1.7 Results

Analysis conducted by Hain and Kenney (2001) suggested that the Cherry Point area has lower densities of marine mammals and lesser numbers of large endangered whales when compared to the VACAPES area. The Wallops Island and Onslow Bay regional density estimates reflect that there may be fewer species found and that they occur in lesser densities at Onslow Bay than Wallops Island. Two exceptions were bottlenose and spotted dolphins, which may be more abundant in the Onslow Bay area. The density estimates presented for Wallops Island are considered satisfactory and representative for the area while those for Onslow Bay are less robust and, while considered the best available, are used here on a provisional basis until better information becomes available.

According to the density information available for Jacksonville, the variety and density of species is lower than those present at the VACAPES area. The only exceptions are the spotted dolphin, the minke whale, and all beaked whales. Even though the North Atlantic Right Whale population is lower in Jacksonville than in the Wallops Island area, it is important to note that the Atlantic Northern Right Whale habitat is near the proposed Jacksonville OPAREA.

All of the available densities are stratified density estimates. They are the best and most reasonable estimates available to represent the distribution and abundance of marine mammals at the proposed locations.

3. ACOUSTIC THRESHOLDS

For this analysis, only cetaceans were considered because of the lack of significant presence of pinnipeds. The USWTR DEIS explains Level A and Level B sonar criteria and thresholds for cetaceans and how they were derived.

3.1 MARINE MAMMAL HARASSMENT CRITERIA

This analysis model labels the results in terms of Level A Takes and Level B Takes and equates the terms to mean permanent threshold shift (PTS) and temporary threshold shift (TTS), respectively. The criteria used for onset-PTS and onset-TTS comes directly from the USWTR DEIS, where, based on analysis, "195 dB re 1 $\mu Pa^2 \cdot s$ is the most appropriate predictor for onset-TTS from a single, continuous exposure." Since data for onset-PTS are not available, analysis was used to determine a relationship between onset-TTS and onset-PTS. "An estimate of 20 dB between exposures sufficient to cause onset-TTS and those capable of causing onset PTS is a reasonable approximation." Thus:

Level B Take (onset-TTS) = 195 to 215 dB re 1 $\mu Pa^2 \cdot s$,

and

Level A Take (onset-PTS) = onset TTS + 20 dB = 215 and greater dB re 1 $\mu Pa^2 \cdot s$.

These criteria provided an acoustic threshold for determining a physical change, either temporary or permanent, in the marine mammal. An additional difficult problem involved addressing behavioral disturbances, where the mammal's normal behavior was disturbed, but the mammal did not suffer an auditory physical change. This type of disturbance is also termed Level B harassment. Lack of scientific data has made determination of a threshold for behavioral effects extremely difficult. Analysis documented in the USWTR DEIS examined the existing data and determined a threshold for behavioral disturbance to be 190 dB re 1 $\mu Pa^2 \cdot s$. Thus,

Level B Take (behavioral disturbance) = 190 to 195 dB re 1 $\mu Pa^2 \cdot s$.

3.2 ACOUSTIC UNITS

The analysis unit used for the harassment thresholds is 1 $\mu Pa^2 \cdot s$ and is designated energy flux density. (Derivation of the equation is contained in appendix B, Underwater Sound Concepts, of the USWTR DEIS.) The equation used in the model is

$$L_E = SPL_{rms} + 10\log_{10}\left(\frac{T}{T_{ref}}\right),$$

where L_E is is the energy flux density level in dB re 1 μPa^2•s, T is the time duration of the signal spread, and SPL_{rms} is the root mean squared sound pressure level, which is defined as

$$SPL_{rms} = 10\log_{10}\left(\frac{1}{T}\int_0^T\left(\frac{p^2(t)}{p_{ref}{}^2(t)}\right)dt\right),$$

where t is time and p is pressure.

By Parseval's theorem (Coleman et al., 1999; Gollisch et al., 2002), which simply stated relates total energy in the time domain to that in the frequency domain, SPL_{rms} is directly related to the output level modeled by Comprehensive Acoustic System Simulation (CASS). If the pulse length is greater that the total eigenray or signal spread, then T is the signal duration expressed in seconds. In this study, this approximation of T is applicable since there is no significant multipath at 1 km.

The total energy flux received at a point in space (L_{E_total}) is the sum of the energy flux densities received at that point and is defined as

$$L_{E-total} = 10 * \log_{10}\left[\sum_{i=1}^{N} 10^{\frac{LEi}{10}}\right] \text{ dB re 1 μPa}^2 \cdot\text{s},$$

where N is the cumulative number of acoustic exposure events.

4. ACOUSTIC SOURCE DESCRIPTIONS AND TRAINING SCENARIOS

Only antisubmarine warfare (ASW) training exercises are currently planned for the USWTR. Four ASW exercise scenarios are addressed in this analysis to capture the scope of sonar operation on the range. The active acoustic systems associated with each training platform (aircraft, ships, submarines, etc.) are identified in this section. This is followed by the four scenario descriptions defining the platforms that participate in each training exercise. The yearly frequency of each scenario occurrence is listed. The criteria for selection of active sources for inclusion in the analysis are presented. Lastly, the operating parameters for each selected source are described to the extent classification restrictions allow. The combination of the training participants, acoustic sources, scenario description, yearly scenario frequency, and, operating parameters are used to fully characterize the use of active sonar systems on the range.

4.1 ACTIVE ACOUSTIC SOURCES

Each of the range users has or deploy active acoustic devices with a varying character of acoustic output that may or may not affect the local marine mammal population. Listed below are the acoustic sources that would be present at the ranges to conduct training exercises.

4.1.1 Surface Ship Sonar

AN/SQS-26CX**—**a hull-mounted passive and active sonar system. The sonar operates in multiple active modes for optimum mission effectiveness.

AN/SQS-53A/B/C**—**an advanced hull-mounted surface ship ASW sonar in the U.S. Navy's inventory; it can detect, identify, and track multiple targets. The sonar operates in multiple active modes for optimum mission effectiveness.

AN/SQS-56**—**a hull-mounted direct-path sonar of the *Oliver Hazard Perry*-class ships.

4.1.2 Surface Ship Fathometer

The surface ship fathometer is used to measure the depth of water from the ship's keel to the ocean floor for safe operational navigation.

4.1.3 Submarine Sonar

AN/BQQ-5**—**the current U.S. Navy standard submarine sonar suite. The basic AN/BQQ-5 consists of sonar transmitting and receiving sphere and towed passive arrays. The AN/BSY-1 active system is basically comparable to the AN/BQQ-5. These two systems are most prevalent in the submarine fleet.

AN/BQQ-10—the acoustic capability of this sonar is analogous to the AN/BQQ-5. The major difference lies in improved processing capabilities; therefore, it was not separately analyzed.

AN/BSY-1 (V)—an integrated system for the mid-frequency bow-mounted submarine active detection system (SADS) sonar; the high-frequency active mine, ice detection and avoidance system (MIDAS) mounted on the sail.

AN/BSY-2—the combat system of the new *Seawolf*-class submarine; its design is based on the AN/BSY-1(V). The major system sensors are a large spherical array (LSA), a low-frequency bow array (LFBA), an active hemispherical array (AHA) below the LFBA, a high-frequency array (HA) in the sail, wide aperture array (WAA) (TB-16, TB-23), and MIDAS. The AN/BSY-2 exists on only three submarines in the Fleet, so it was not included in the modeling.

4.1.4 Submarine Fathometer

The fathometer is used to measure the depth of water from the submarine's keel to the ocean floor for safe operational navigation.

4.1.5 Submarine Auxiliary Sonar Systems

AN/BQS-14/15—an under-ice navigation and mine-hunting sonar that operates at mid to high frequency and employs a receiver, as well as a projector. Later versions, i.e., the Submarine Active Detection Sonar (SADS), have been integrated as part of the AN/BSY-1 and -2.

AN/WQC-2A—an underwater sonar communications system that has two frequency bands: mid-frequency (MF) (1.45 to 3.1 kHz) and high frequency (HF) (8.3 to 11.1 kHz). The HF band will primarily be used for range communications at USWTR.

4.1.6 Aircraft Sonar Systems

Aircraft sonar systems that operate on the ranges include sonobuoys and dipping sonar. Sonobuoys may be deployed by P3 aircraft or helicopters; dipping sonars are used by helicopters. A sonobuoy is an expendable device used by aircraft for the detection of underwater acoustic energy and for conducting vertical water column temperature measurements. Most sonobuoys are passive, but some can generate active acoustic signals, as well as listen passively. Dipping sonar is an active or passive sonar device lowered on cable by helicopters to detect or maintain contact with underwater targets.

AN/AQS-13 Helicopter Dipping Sonar**—**a long-range, active, scanning sonar that detects and maintains contact with underwater targets through a transducer lowered into the water from a hovering helicopter.

AN/AQS-13F**—**the latest version of the helicopter dipping sonar AN/AQS-13.

AN/SSQ-62C Directional Command Active Sonobuoy System (DICASS)**—**This sonobuoy operates under direct command from ASW fixed-wing aircraft (P-3C). The system can also determine the range and bearing of the target relative to the sonobuoy's position. After water entry, the sonobuoy transmits sonar pulses (continuous waveform (CW) or linear frequency modulation (FM)) upon command from the aircraft. The echoes from the selected activating signal are processed in the buoy before being transmitted to the receiving station onboard the launching aircraft.

AN/AQS-22 Airborne Low-Frequency Sonar (ALFS)**—**the U.S. Navy's dipping sonar system for the carrier-borne SH-60F and light airborne multipurpose system (LAMPS) SH-2/SH-60B/R helicopters, the latter being flown from cruisers, destroyers, and frigates. ALFS employs deep- and shallow-water capabilities and operates at mid-frequency.

4.1.7 Torpedoes

Torpedoes are the primary ASW weapon used by surface ships, aircraft, and submarines. Active torpedoes transmit an acoustic signal to ensonify the target and use the received echoes for guidance. All torpedoes to be used at the USWTR are inert (nonexplosive) weapons; they are the Mk 48 and Mk 48 advanced capability (ADCAP) heavyweight torpedoes and the Mk 46, Mk 50, and Mk 54 advanced lightweight (ALW) torpedoes. Exercise torpedoes (EXTORPs) are inert units (no warhead) with operating sonar and engines. Recoverable Exercise Torpedoes (REXTORPs) are inert training units that have no mobility or acoustic capability to search, detect, and pursue targets.

4.1.8 Acoustic Device Countermeasures

Several types of countermeasure (CM) devices are scheduled to be deployed in the USWTR, including the Acoustic Device Countermeasure (ADC) Mk 1, Mk 2, Mk 3, and Mk 4. CM devices are submarine simulators and act as decoys to avert localization and torpedo attacks. CMs may be towed or free-floating sources.

4.1.9 Training Targets

Two types of training targets will be used at USWTR: the Mk 30 Acoustic Target and the MK 39 Expendable Mobile ASW Training Target (EMATT). ASW training targets are used to simulate submarines as an ASW target in the absence of participation by a submarine in an exercise. The training targets are equipped with acoustic projectors emanating sounds to simulate submarine acoustic signatures and echo repeaters to simulate the characteristics of the reflection of a sonar signal from a submarine.

4.1.10 Tracking Pingers

Tracking pingers are installed on training platforms to track the position of underwater vehicles (GPS type systems are used to track in-air and surface platforms). The pingers generate a precise, preset acoustic signal for each target to be tracked.

4.2 TRAINING SCENARIO DESCRIPTIONS

ASW training exercises are planned for USWTR. Four scenarios have been defined to capture the scope of activities by range users. The active acoustic systems associated with each platform are described below and characterized for incorporation in the analysis.

4.2.1 ASW Scenario Exercise Descriptions

Submarines, surface ships, and aircraft conduct ASW individually or as a coordinated force against a submarine target. Submarine targets include submarines or mobile targets that simulate the operations of a submarine. ASW operations and other training exercises are complex and highly variable. To best characterize and clarify these exercises for environmental effect analysis purposes, each scenario must identify the types of participating platforms and the number of occurrences expected yearly.

4.2.1.1 Scenario 1: Air Undersea Warfare—One Aircraft vs One Submarine. In this scenario, an aircraft flies over the range area and the crew conducts a search for a target submarine. After the crew detects and localizes the submarine, a simulated attack is initiated. Each exercise period typically involves the firing of one EXTORP, either a Mk 46 or Mk 50. Additional attack phases are conducted with simulated torpedo firings or REXTORPs.

4.2.1.2 Scenario 2: Surface Ship Undersea Warfare—One Ship with One Helicopter vs One Submarine. In scenario 2, a ship, carrying a helicopter, crosses the range area and conducts a broad area search for a target submarine. When the submarine's approximate position has been determined, the ship deploys the helicopter to localize and attack. In some exercises, the ship conducts its own "close-in" attack simulation. Each exercise period typically involves the firing of a Mk 46 or Mk 50 EXTORP by the ship, or the helicopter, or, in some cases, both. Some ships carry two helicopters, but only one participates in the exercise at any one time. While the ship is searching for the submarine, the submarine may practice simulated attacks against the ship.

The scenario 2 model reflects shared prosecution time and shared active sonar time between the surface ship and helicopter, with each being active 50% of the time. The training exercise is modeled in two operational phases for the surface ships: a search period for the target and a prosecution period. The surface sonar operational characteristics are adjusted for the different modes of operation for these two phases/periods.

4.2.1.3 Scenario 3: Submarine Undersea Warfare—One Submarine vs Another Submarine. In scenario 3, two submarines on the range practice locating and attacking each other. If only one submarine is available for the exercise, it practices attacks against a target simulator or a range support boat, or it practices shallow-water maneuvers without any attack simulation. During this scenario, the attacking submarine may launch an Mk 48 REXTORP.

4.2.1.4 Scenario 4: Battlegroup Exercise—Two Ships and Two Helicopters vs One Submarine. Scenario 4 is the same as scenario 2, but with two ships and two helicopters searching for, locating, and attacking one submarine with a Mk 46 or Mk 50 torpedo. While the ships are searching for the submarine, the submarine may practice simulated attacks against the ships. As in scenario 2, the analysis reflects shared prosecution time between the surface ships and helicopters with each being active 50% of the time. The operational scenario provides for the two helicopters to be active simultaneously for a period of time. Also, distributions between search and prosecution phases of operation for the surface sonar are incorporated.

4.2.2 Number of Training Events Per Year

The four training scenarios would each be conducted a finite number of times each year at the USWTR (table 4-1). The Navy also conducts broader scale exercises (Joint Task Force Exercise (JTFEX), Composite Training Unit Exercise (COMPTUEX), and Independent Deployer Exercise (INDEX)) in their larger East Coast operations areas. In the case of these larger exercises, some units may break off and conduct operations on the USWTR, following one of the described operational scenarios. On any given day, the training scenario would vary somewhat from the depictions in this report, but the total of all these scenario runs represents the typical annual spectrum of training activities on the range. Scenario four represents the busiest day on the range having the greatest number of participants.

Table 4-1. Annual Tally of USWTR ASW Training Scenarios

Scenario	Description	Duration	Stand-Alone Occurrences	JTFEX, COMPTUE, and INDEX	Yearly Exercise Total for USWTR
1	Air USW	6 hours	88	10	98
2	Surface USW	6 hours	30	0	30
3	Submarine USW	6 hours	15	0	15
4	Battlegroup	6 hours	4	14	18

4.3 ACOUSTIC SOURCE SELECTION

Based on the acoustic source characteristics, five acoustic sources were selected for marine mammal acoustic effect analysis. The other acoustic sources used during training were determined to have non-problematic characteristics not requiring further examination. The criteria for determining whether a source could potentially be considered non-problematic included:

- The source level for a single ping transmission was < 205 dB//1 μPa at 1 m.
- The source has an operating frequency > 100 kHz.
- The source has a transmission pattern pointing at the ocean bottom with a beamwidth of ±30° or less.

The first criterion is based on the low potential for sources at this source level with a pulse length of less than or equal to 1 second to exceed the thresholds for Level A and Level B harassment. For these types of sources, the duration of the active period and the repetition rate of the ping still need to be considered, but typically the source is not an acoustic problem. Acoustic signals at 100 kHz and above attenuate rapidly during propagation (approximately 30 dB per kilometer or more), while incurring additional signal spreading losses, which result in very short propagation distances. Again, if the source has a high ping repetition rate and is active for an extended time period, it will need to be examined more closely. The third criterion is in consideration of the fathometer, which is pinging on the ocean bottom. This system could potentially harass a mammal if the mammal was traveling beneath the hull of the ship for an extended period of time. This type of occurrence is considered highly unlikely.

Although the parameters are classified, based on the source level, ping duration, and repetition rate, lightweight torpedoes were examined and determined not to be an acoustic problem. CM operational characteristics are also classified, but the source level is less than 205 dB//1 μPa criterion; however, its active duty cycle and repetition rate required a closer analysis. It was determined to be non-problematic. The results are documented in an NUWC, Division Newport Technical Memo (Lazauski, 2002).

The following are those acoustic sources modeled in this impact analysis:

1. AN/SQS-53C operated by surface ships,
2. AN/SQS-56 operated by surface ships,
3. AN/BQQ-5 operated by submarines,
4. ALFS dipping sonar by helicopters,
5. MK 48 torpedo sonar.

Although the AN/SQS-26CX sonar system does not meet the exclusion criteria listed above, its operational characteristics are very close to those of the AN/SQS-53C. In all modes of operation to be used on the range, the two systems are either identical or the AN/SQS-53C is a slightly worse case. As a result, the AN/SQS-53C sonar system was used as the representative system for the model analysis.

In each exercise scenario, the above sources would be employed in various combinations. Other sources are non-problematic based on the rationale above and/or additional analysis. Table 4-2 provides a list of active acoustic sources that were deemed to be non-problematic. Each source is described and not further addressed from an acoustic effect standpoint. Some of the operating characteristics of these sources are classified and are, therefore, described in general terms.

Table 4-2. Other Acoustic Sources Not Considered Further

Acoustic Source	Comment
Weapon and Target Mk 84 Tracking Pinger	Mounted on all in-water exercise participants. Source level of 190–194 dB//1 μPa centered between 13 and 37 kHz.
Acoustic CMs	Separate analysis proved source level is non-problematic. Report is classified.
Fathometers (surface ship and submarine)	Narrow transmission beam focused at ocean bottom.
UQC (surface ship and submarine)	Source levels 188–193 dB//1 μPa between 8–11 kHz.
Mk 30 Target	Source level is non-problematic but is classified.
Mk 39 EMATT	Source level is non-problematic but is classified.
DICASS Sonobuoys	Source level is non-problematic at 201 dB//1 μPa.
Remote Minehunting System	Source frequency is above 100 kHz
Mk 46/Mk 50/Mk 54 Lightweight Torpedoes	Analysis showed these are not problematic. Source levels are classified.

4.4 SOURCE OPERATIONAL DESCRIPTIONS

Several parameters were defined for each of the sources modeled. These parameters include the center frequency, repetition rate, pulse length, sound pressure level, horizontal beamwidth, vertical beamwidth, frequency of use, mobility, and operating depths. A brief operational description of each modeled source is provided below.

Each source was modeled so that it could be applied to any of the four training scenarios. This was achieved by calculating a take rate for each source based on either the duration of use or the specific number of times used. Additionally, consistent vessel propagation paths and common fixed positions for stationary sources facilitated the analysis. These paths and points were chosen to capture a representative variation in the acoustic properties expected over the training area. The representations allow for assessment of the effects of each scenario on each species once complex propagation calculations have been completed for each of the sources. Calculation of the total annual effects becomes a relatively simple series of spreadsheet level calculations.

Beyond these general assumptions, some specific assumptions were made of each of the sources.

4.4.1 DICASS Sonobuoys

DICASS sonobuoys would be employed by helicopters and P-3 patrol aircraft in scenario 1 and by helicopters in scenarios 2 and 4. Due to the exclusion criteria, they are not modeled, but their use shares time with the helicopter dipping sonar. When helicopters are involved in a scenario, DICASS buoys operate 50% of the time with two DICASS buoys deployed per aircraft. The rest of the time, helicopters are assumed to employ their dipping sonar. Over the next several years, all Fleet ASW helicopters will evolve to the new SH-60R variant, which will employ either sonobuoys or dipping sonar on any given mission.

4.4.2 Dipping Sonar

Dipping sonar would be employed in scenarios 1, 2, and 4 by helicopters: they are assumed to be employed 50% of the time that helicopters are used (the remaining 50% of helicopter time, DICASS sonobuoys are used). There are two types of dipping sonar: the AN/AQS-13 and the AN/AQS-22 ALFS. Rather than model both of these dipping sonars, only the ALFS was modeled for several reasons. Both dippers have similar source levels, but ALFS operates at a lower frequency and, therefore, has more potential to be problematic due to less attenuation at low frequencies. Modeling only the ALFS is slightly conservative, but coupled with the fact that the ALFS will ultimately replace the AN/AQS-13, this assumption simplified the acoustic effect calculation. Within 10 years, all Navy dipping sonar will be ALFS.

Dipping sonars were modeled as stationary sources with the following pattern. Three specific locations on the range were selected based on the range bathymetry. Two locations were in the shallower depth regime and the third was in the deeper regime. Operationally, the source will be deployed to either a deep or shallow depth. In the model, the source was deployed to the shallow depth at each location. Additionally, the source was modeled at a deeper depth at the deeper location. ALFS was modeled for a period of 5 minutes at each depth and location. (It should be noted that the term “low frequency” in the ALFS name is somewhat misleading. Although the ALFS operates at a lower frequency than the system it will replace (the AN/AQS-13), its operating frequency is in the range more commonly called mid-frequency.)

4.4.3 Surface Ship Sonar (AN/SQS- 53C)

The AN/SQS-53C, one of two surface ship sonars that were modeled, would be employed by surface ships in scenarios 2 and 4. The AN/SQS-53C is in use on approximately 70% of the surface ships that employ active sonar. It also has a higher source level and unique operating characteristics relative to the other surface ship sonar (AN/SQS-56). The surface ship sonar was modeled as a moving source with a fixed depth. Two modes of operation are modeled: search and target (sometimes referred to as track mode). The distribution between search time and target time has been defined as 67% and 33%, respectively. The source characteristics were adjusted in the analysis for each mode of operation.

4.4.4 Surface Ship Sonar (AN/SQS-56)

The AN/SQS-56, the second surface ship sonar that was modeled, would be employed by surface ships in scenarios 2 and 4. The AN/SQS-56 is employed on approximately 30% of the surface ships that employ active sonar. As with the AN/SQS-53C, this sonar was modeled in both search and target modes with the source characteristics adjusted for each.

4.4.5 Submarine Sonar

The AN/BQQ-5 submarine sonar was modeled as the most representative submarine system. Its employment is included only in scenario 3 (submarine versus submarine). In that scenario, one of the two submarines was assumed to remain silent. The prosecuting submarine was modeled to ping once per hour from one of three stationary positions to confirm targeting solutions. It was modeled at two operating depths and several locations on the USWTR with the average result used to achieve a take result for the scenario. Although the submarine moves during an exercise, it was modeled as a stationary source to reflect the fact that its active sonar is rarely used.

4.4.6 Torpedoes

The Mk 48 EXTORPs are analyzed in scenario 3. As with the AN/BQQ-5 submarine sonar, the Mk 48 was modeled at two operating depths on the SWTR, but as a moving target.

4.5 ACOUSTIC SOURCE MODEL INPUTS

Establishing the acoustic effects on marine mammal populations in the USWTR areas requires the identification of the following source information:

- Navy acoustic sources to be used at the training range (section 4.3),
- source center frequencies,
- source output levels,
- source pulse length and repetition rate,
- source beamwidth (horizontal and vertical),
- operating depth(s) at which these sources are to be modeled, and
- number of training days these acoustic sources are to be introduced to USWTR waters.

Table 4-3 depicts the combinations of acoustic sources used in the four SWTR training scenarios, as well as the annual estimates of training events by scenario. The operational duty cycles are provided for each source. The two surface sonars also provide duty cycles that reflect the two operational modes modeled: search mode and target mode.

For this analysis, the number of training events and their associated sources were distributed evenly on a seasonal basis. Inputs for this model were further refined in terms of the acoustic source used by different scenarios on a yearly training-events basis (see table 4-4).

Table 4-5 lists the applicable vessel speeds used in the modeling for each source. Stationary sources include dipping sonar and the AN/BQQ-5 submarine sonar. Submarines are not stationary during an exercise, but the limited use of their sonar allows them to be effectively modeled as stationary.

Table 4-3. Acoustic Sources Used by Training Scenario and Operational Duty Cycles

Scenario	Participants	Acoustic Sources	Operational Duty Cycles Applied	Estimated SWTR Training Events/Yr
1	P3 or helicopter vs submarine	ALFS DICASS	50% ALFS/50% DICASS	98
2	One helicopter and one surface ship vs submarine	ALFS DICASS AN/SQS-53C AN/SQS-56	50% ALFS/50% DICASS; 50% helo/50% surface ship; 70% use (67% search/33% target) 30% use (67% search/33% target)	30
3	Submarine vs submarine	AN/BQQ-5 Mk 48	Stationary use Run time	15
4	Two surface ships and two helicopters vs submarine	ALFS DICASS AN/SQS-53C AN/SQS-56	50% ALFS/50% DICASS; 50% helo/50% surface ship; (50% each helo/ship team) 70% use (67% search/33% target) 30% use (67% search/33% target)	18

Table 4-4. Yearly Acoustic Sources by Scenario

Participants	Scenario 1	Scenario 2	Scenario 3	Scenario 4
AN/SQS-56	0	9	0	11
AN/SQS-53C	0	21	0	25
AN/BQQ-5	0	0	15	0
Mk 48	0	0	25	0
DICASS (2 units/deployment)	196	30	0	36
ALFS	98	15	0	18

Table 4-5. Modeled Source Platform Speeds

Source Type	Modeled Speed (km/hr)
AN/SQS-56	18.52
AN/SQS-53C	18.52
AN/BQQ-5	NA
Torpedoes	Classified
ALFS	Stationary (three locations)

5. UNDERWATER SOUND PROPAGATION ANALYSIS

The initial modeling step consists of calculating the acoustic propagation loss functions. For Level A analysis, studies showed that spherical spreading loss provided a good approximation, as explained in section 5.1. For Level B analysis, modeling for the combination of conditions is implemented. The combinations include variation by season, the depth regions defined for the analysis, and the source's operational characteristics (frequency, vertical and horizontal beam pattern, ping length, depth). Each analysis run incorporates bottom and surface reflection losses, multi-path reception of sound, absorption, and the ray traces resulting from the seasonal sound speed profile (SSP).

5.1 LEVEL A PROPAGATION MODELING

In comparing the threshold level for Level A harassment to the source characteristics for the systems analyzed, it was apparent that detailed propagation analysis would overcomplicate the analysis without significant benefit. This is due to the short distances necessary to reach the Level A thresholds with spherical spreading losses alone. An example is shown in table 5-1 for a source assumed to ping with a pulse width of 1 second. As a result of these short distances, few or no surface and bottom interactions occur and absorption is negligible in comparison to the spreading losses. Also, there is little accumulation of energy from multiple pings above or near the thresholds for the moving sources, so the Level A harassment range corresponds closely to the range for each ping independently. Thus, to determine the Level A harassment range for each source, propagation losses were modeled equal to spherical spreading. For sources where multiple pings from a single point would occur, such as the dipping sonar, the harassment range was defined by the total energy flux from all pings at each transmission point.

Some caveats exist for the Level A analysis, all of which produce an expectation of few or no Level A takes. First, for physically larger sources, specifically the surface ship and submarine sonars, the Level A harassment ranges can be close to the acoustic transducers. In this circumstance, the actual level of harassment received by any mammal will be limited by shielding effects of the sonar's structure. Second, the analysis assumes that the acoustic energy is constant throughout the vertical water column at a given horizontal range from the source. For short distances, the slant range between the source and mammal may significantly exceed the horizontal distance, resulting in a lower energy level being received. Third, for lower power sources, the harassment range may be less than the size of the mammal itself. Lastly, the Level A harassment ranges for all sonars correspond to distances where striking the animal is possible. Mitigation to avoid ship strikes of mammals simultaneously eliminates the potential for Level A harassment. Despite the very low likelihood of Level A harassment, its assessment (using the described methodology) was included for completeness.

Table 5-1. Level A Harassment Range Example

Source Level (dB//1μPa @1 m)	Ping Length (s)	Total Energy Flux (dB//1 μPa^2 s)	Level A Threshold (dB re 1 μPa^2 s)	Allowable Spreading Loss (dB)	Distance to Reach Level A Threshold (20 Log R) (m)
215	1	215.00	215	0.00	1.00
220	1	220.00	215	5.00	1.8
225	1	225.00	215	10.00	3.1
230	1	230.00	215	15.00	5.6

5.2 LEVEL B PROPAGATION MODELING

For Level B harassment, propagation analysis is performed using the Gaussian RAy Bundle (GRAB) model for horizontally stratified and range-variant environments. GRAB provides detailed multipath information as a function of range and bearing. The Gaussian beam approach provides a means for estimating energy leakage out of ducts and into shadow zones, significantly improving the ray-based model predictions and extending the operational realm to lower frequencies. GRAB allows input of range-dependent environmental information so that, for example, as the bottom depths and sediment types change across the range, their acoustic effects can be modeled. The propagation analysis uses the input data described in sections 5.1 through section 5.3.5. The source's frequency, ping length, and vertical beam pattern are also used.

Range-dependent models, such as those based on the parabolic equation (PE) (for example, the University of Miami PE, Finite Element PE, and Navy Standard PE), are accurate and were considered, but using these modes requires increasingly longer computer run times as the source frequency increases. While there is no inherent frequency limitation to the PE model, the higher the acoustic frequency and fidelity of the environmental inputs modeled, the more memory and computer time required.

The GRAB eigenray propagation loss program has received full Oceanographic and Atmospheric Master Library (OAML) approval for high frequencies (above 10 kHz). The GRAB model has also received full approval from OAML for 600 Hz and above. For each path to a given receive point the total energy from all eigenrays is used to produce the propagation loss function. An illustration of this is provided in figure 5-1.

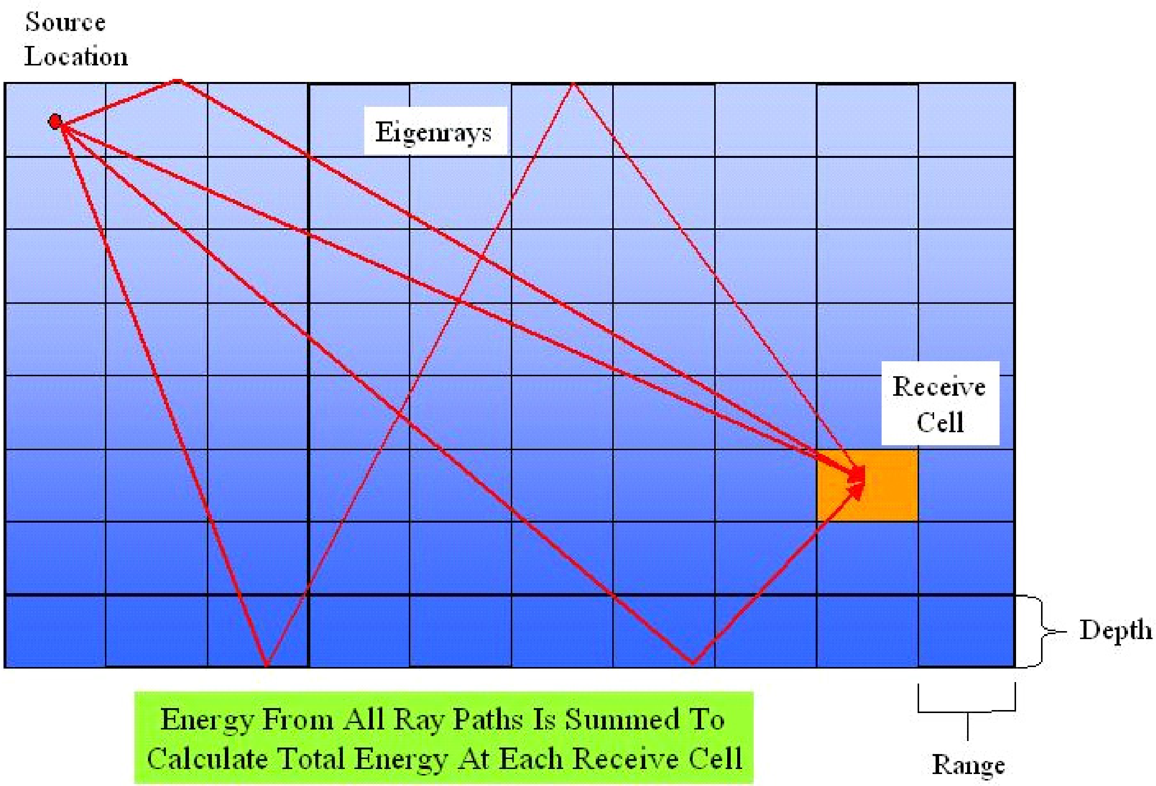

Figure 5-1. CASS/GRAB Propagation Loss Calculations

5.3 ACOUSTIC ENVIRONMENT

Several environmental inputs are necessary to model the acoustic propagation on the prospective ranges: bathymetry, wind speeds for each season, SSPs for each season, and bottom characteristics. Wind speeds are averaged for each season to correspond to the seasonal velocity profiles.

5.3.1 Bathymetry

Bathymetry data for the Onslow Bay site was obtained from the National Oceanographic and Atmospheric Administration (NOAA) National Geographical Data Center, Coastal Relief #1 and #2 East Coast CD-ROM databases. A map of these data for the Onslow Bay site is shown in figure 5-2. The bathymetry contours were extended from the surveyed area into deeper water to cover the extent of acoustic propagation. This extrapolation permits uniform acoustic analysis of the area. The training range area is represented as a 40-km by 50-km rectangle. The bathymetry map (150 km by 110 km) covers a larger region than the range area.

Bathymetry data for the Wallops Island site (figure 5-3) was obtained from the National Geophysical Data Center, Coastal Relief Model (volume II). To use these data in the acoustic propagation model, it was translated and rotated onto x-y coordinates to be consistent with GRAB input parameters. The bathymetry contours did not have to be extended from the surveyed area because the database covered the entire area. The other edges of the region were automatically treated as projections of the edge for the analysis. The training range area is represented as a 40-km by 50-km rectangle. The bathymetry map (130 km by 100 km) covers a larger region than the range area, so that acoustic energy propagating off the training area could be accounted for.

Bathymetry data for the Jacksonville site were obtained from the Naval Oceanographic Office (NAVOCEANO) Digitized Bathymetric Data Base-Variable Resolution (DBDB-V). A map of this area is shown in figure 5-4. The training range area is represented by a 35-km by 48-km rectangle. The resulting bathymetry map covers a larger area than the proposed range to account for acoustic energy propagating off the training area.

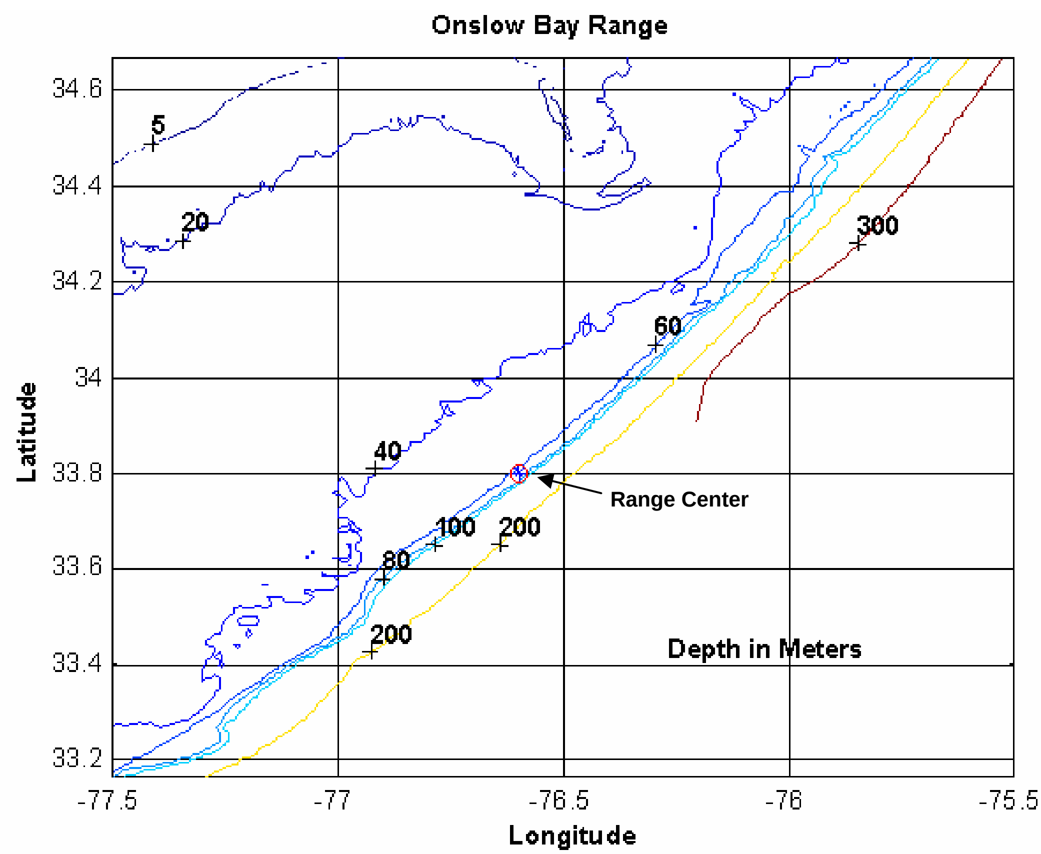

Figure 5-2. Onslow Bay Bathymetry (Range Center at 33.8° N and 76.6° W)

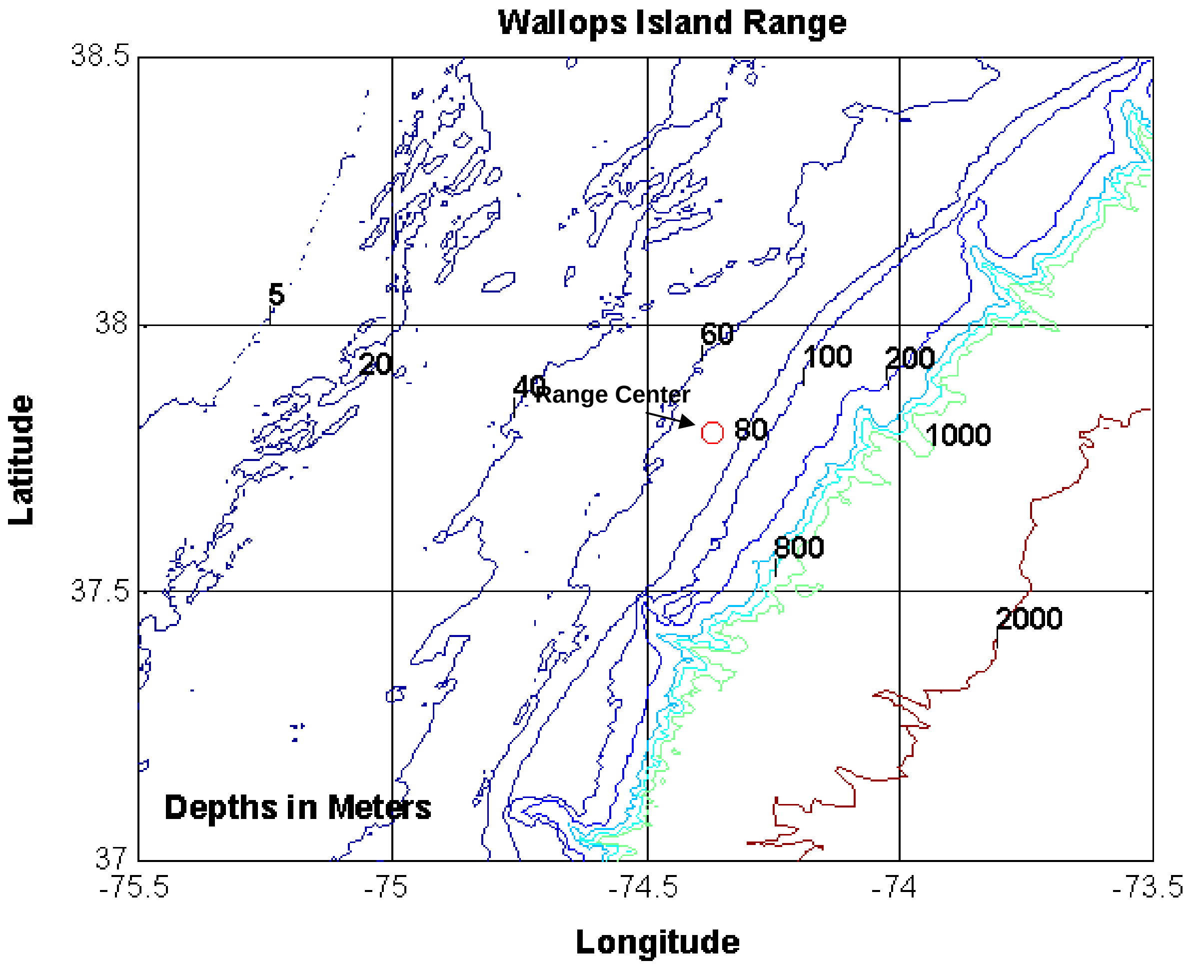

Figure 5-3. Wallops Island Bathymetry (Range Center at 37.8° N and 74.36° W

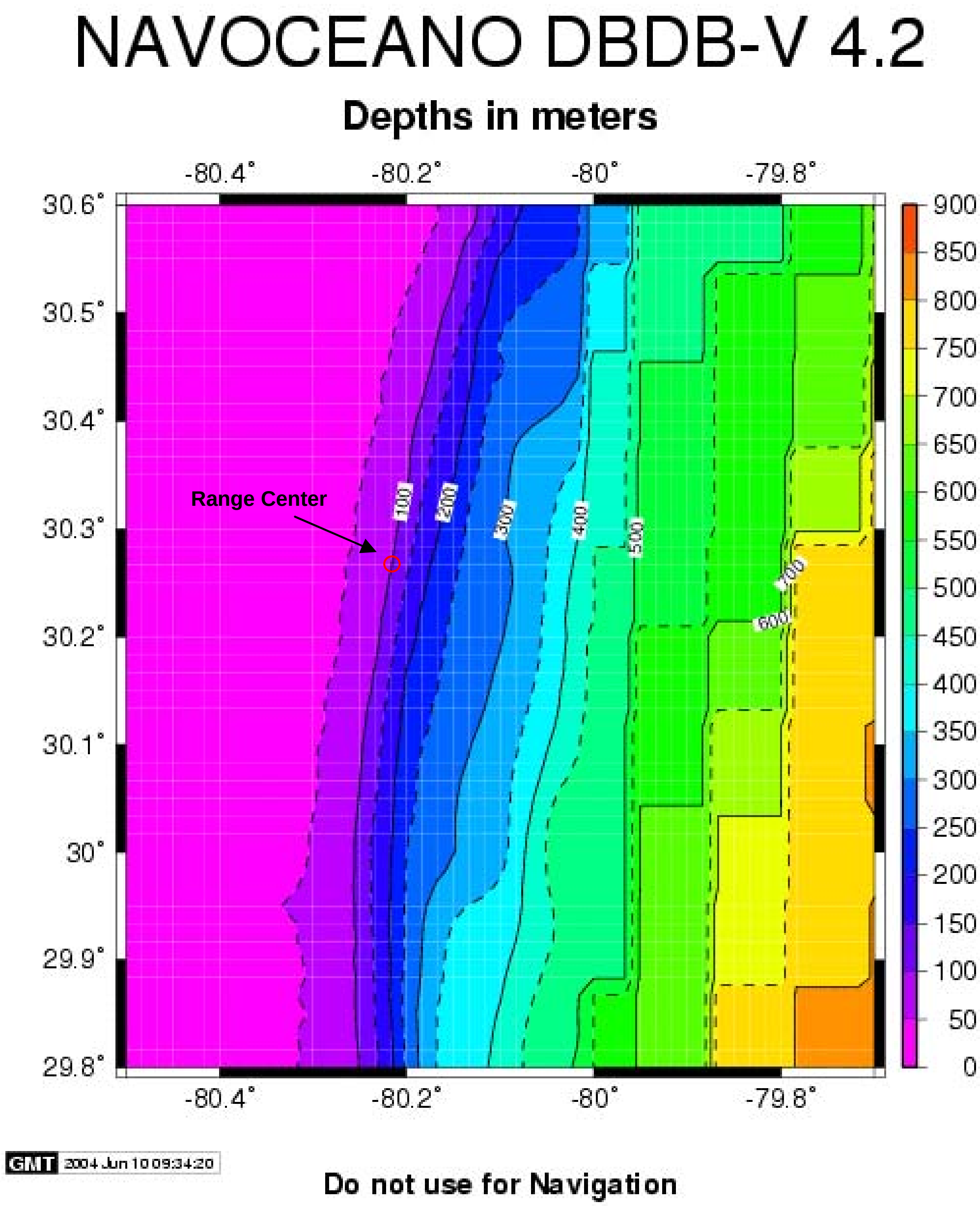

Figure 5-4. Jacksonville Bathymetry (Range Center at 30.27° N, 80.22° W)

5.3.2 Wind Speed Data

For Onslow Bay, wind speed data were collated from the National Data Buoy Center (NDBC) website (www.ndbc.noaa.gov/station_history.phtml?$station=41001) maintained by NOAA. The data used covered wind speed measurements from June 1976 through December 1993.

Data from Buoy 41001 is the nearest representative offshore measurement station to Onslow Bay. It is located 150 nmi east of Cape Hatteras at position 34.68° N lat., 72.23° W long. The compiled average wind speed data by month and season are shown in table 5-2. The wind speed data for VACAPES shown in table 5-3 were collected from the NDBC maintained by NOAA.

Wind speed data for Jacksonville were collected from Mine Warfare Pilot Kings Bay. The seasonal wind speeds were averaged for each season and ranged from 7.3 to 9.8 m/s. These averages are based on more than 96 observations. These are compiled in tables 5-2, 5-3, and 5-4.

Table 5-2. Seasonal Wind Speed Average for Onslow Bay

Season	Wind Speed (m/s)
Winter	9.4
Spring	8.0
Summer	6.1
Autumn	7.3

Table 5-3. Seasonal Wind Speed Average for Wallops Island

Season	Wind Speed (m/s)
Winter	11.1
Spring	11.5
Summer	9.0
Autumn	10.0

Table 5-4. Seasonal Wind Speed Average for Jacksonville

Season	Wind Speed (m/s)
Winter	9,8
Spring	7.7
Summer	7.3
Autumn	9.4

5.3.3 Surface Loss Model

The surface loss model used in CASS was assessed using at-sea measured propagation loss data. These data were acquired as part of a comprehensive side-by-side test of mid-frequency and low-frequency sonars during February 1992 (Lanza, 1992). Based on an analysis of these data, the most applicable surface reflection coefficient model for the marine mammal acoustic effect assessment within the CASS environment is the modified-Eckart model, which was used (Ward, 2001).

5.3.4 Sound Speed Profiles (SSPs)

An investigation was made to determine the seasonal acoustic characteristics of the three sites. SSPs from 1980 to the present for Onslow Bay and Wallops Island were downloaded from the NODC Oceanographic Profile Data Base (www.nodc.noaa.gov/cgi-in/JOPI/jopi). For Onslow Bay, a total of 346 SSPs were obtained. Of these, 35 were determined to have inconsistent data and were eliminated from use. Of the remaining profiles, 55 were on the continental shelf (less than 60-m depth), 83 were at the shelf break (between 60-m and 200-m depth) and 173 were on the continental slope (greater than 200-m depth). The three sets were then grouped by season. A summary for the Onslow Bay SSPs is provided in table 5-5. For Wallops Island, a total of 1183 profiles were available and are summarized in table 5-6.

The SSPs for Jacksonville were obtained from the NAVOCEANO Generalized Digital Environmental Model (GDEMV). Comparison of these profiles to those of the other sites reveals that the Jacksonville range area is similar to Onslow Bay. Both areas are subject to daily variations attributed to the close proximity of the Gulf Stream.

Table 5-5. Onslow Bay SSP Distribution

Depth Regime	Spring	Summer	Autumn	Winter
Continental Shelf	9	13	3	30
Shelf Break	14	18	9	42
Continental Slope	58	26	20	69

Table 5-6. Wallops Island SSP Distribution

Depth Regime	Spring	Summer	Autumn	Winter
Continental Shelf	119	278	23	259
Shelf Break	78	101	18	143
Continental Slope	24	92	48	10

From each of the depth regime and season combinations, the best representative SSP was selected by determining which profile most closely matched the average of the profiles in each depth regime and season. To get the average, each profile was stratified into 1-m-depth increments. Interpolation between data points was performed to produce a uniform number of data points in each profile. The average profile was calculated by averaging each of the depth layers for all the profiles in the set. The best profile used in the analysis was determined by finding that profile, whose sum of the squares of the difference from the average profile was the minimum.

The best continental slope profiles selected were not deep enough to define the sound speed environment over the deeper parts of the range space to the CASS/GRAB model. Therefore, to define the deeper parts of the slope SSPs, the appropriate lower section of the deepest profile was added onto the selected profile. The SSPs used for the Onslow Bay, Wallops Island, and Jacksonville analyses are shown in figures 5-5, 5-6, and 5-7, respectively.

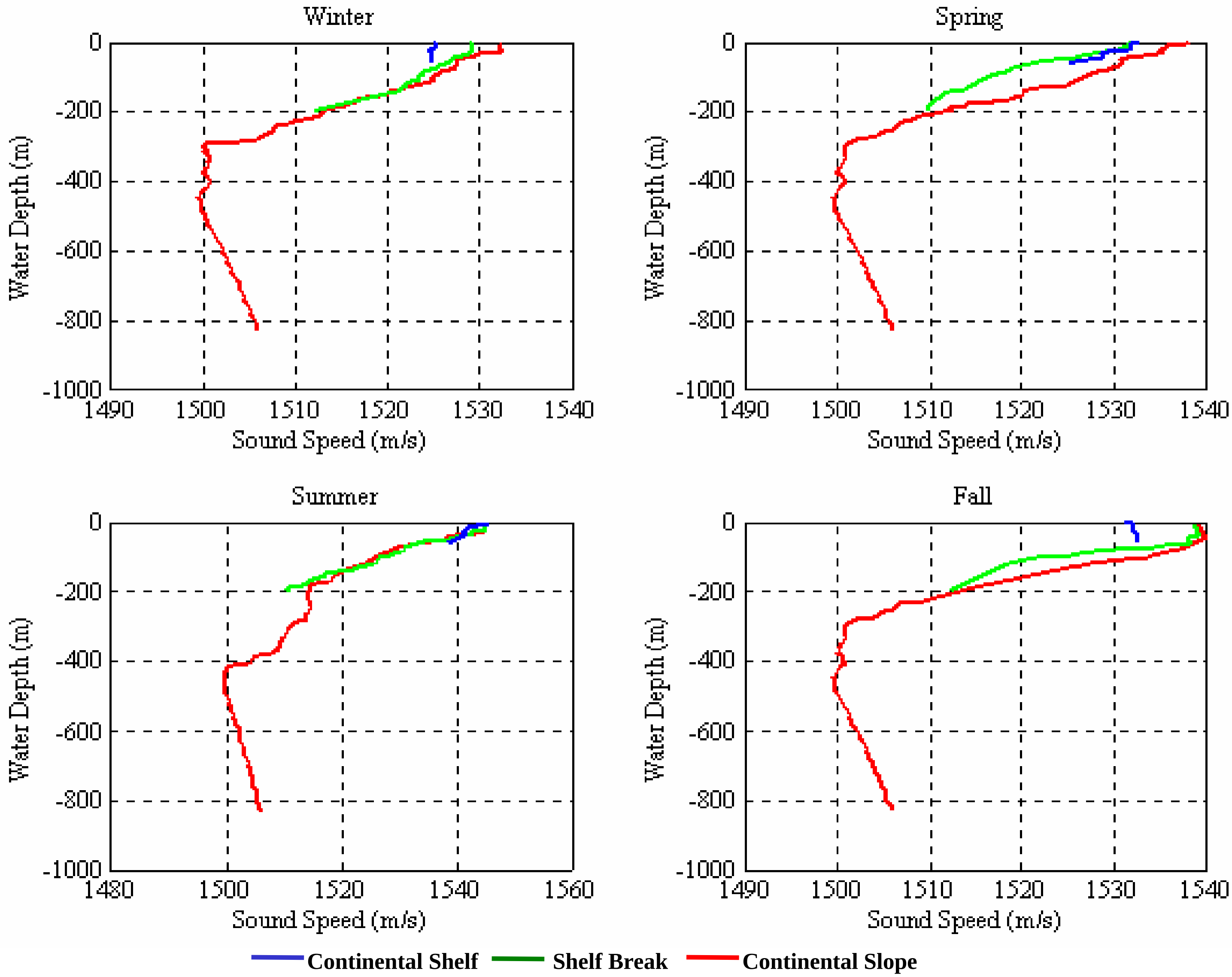

Figure 5-5. SSPs for Onslow Bay Analysis

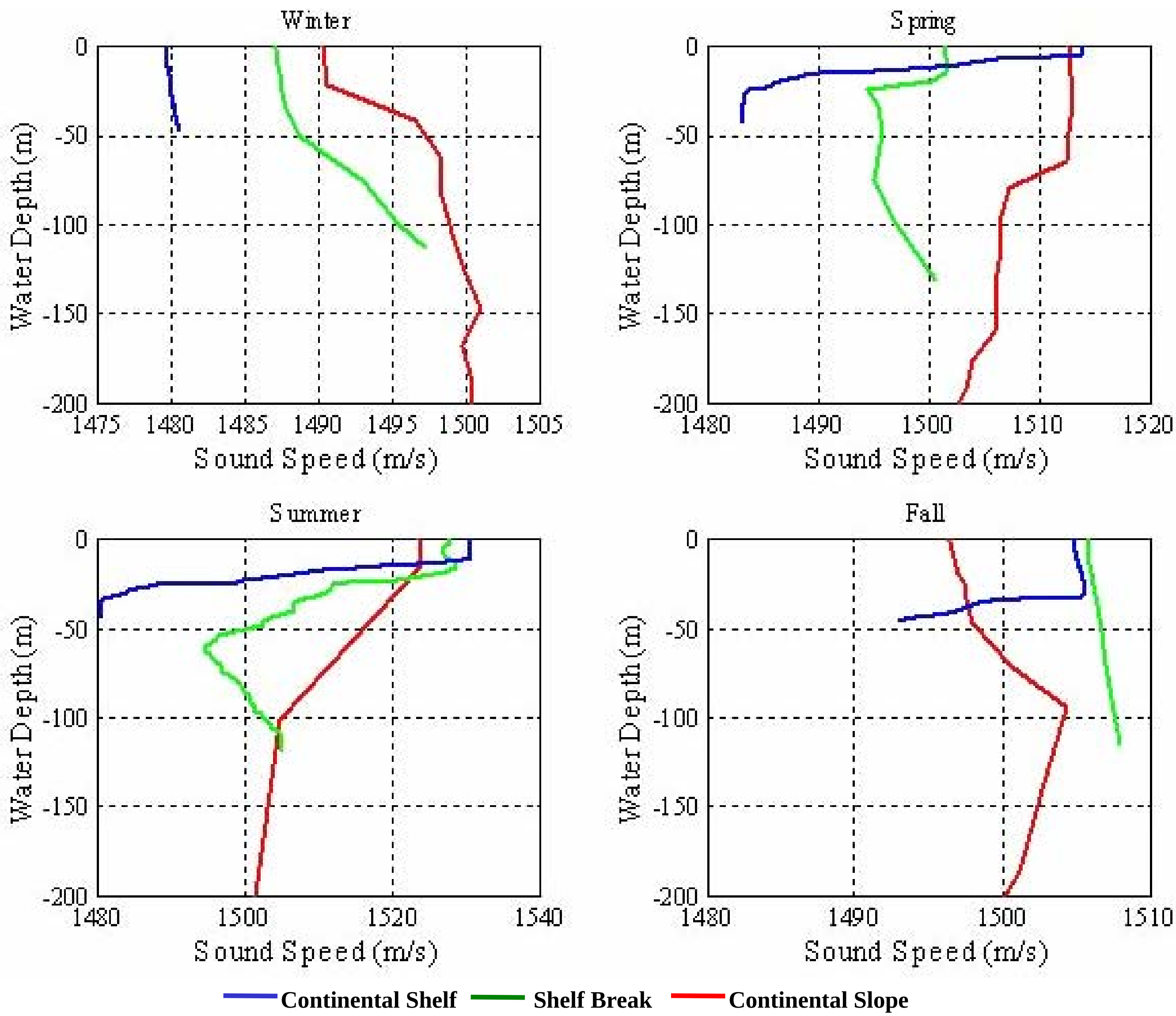

Figure 5-6. SSPs for Wallops Island Analysis

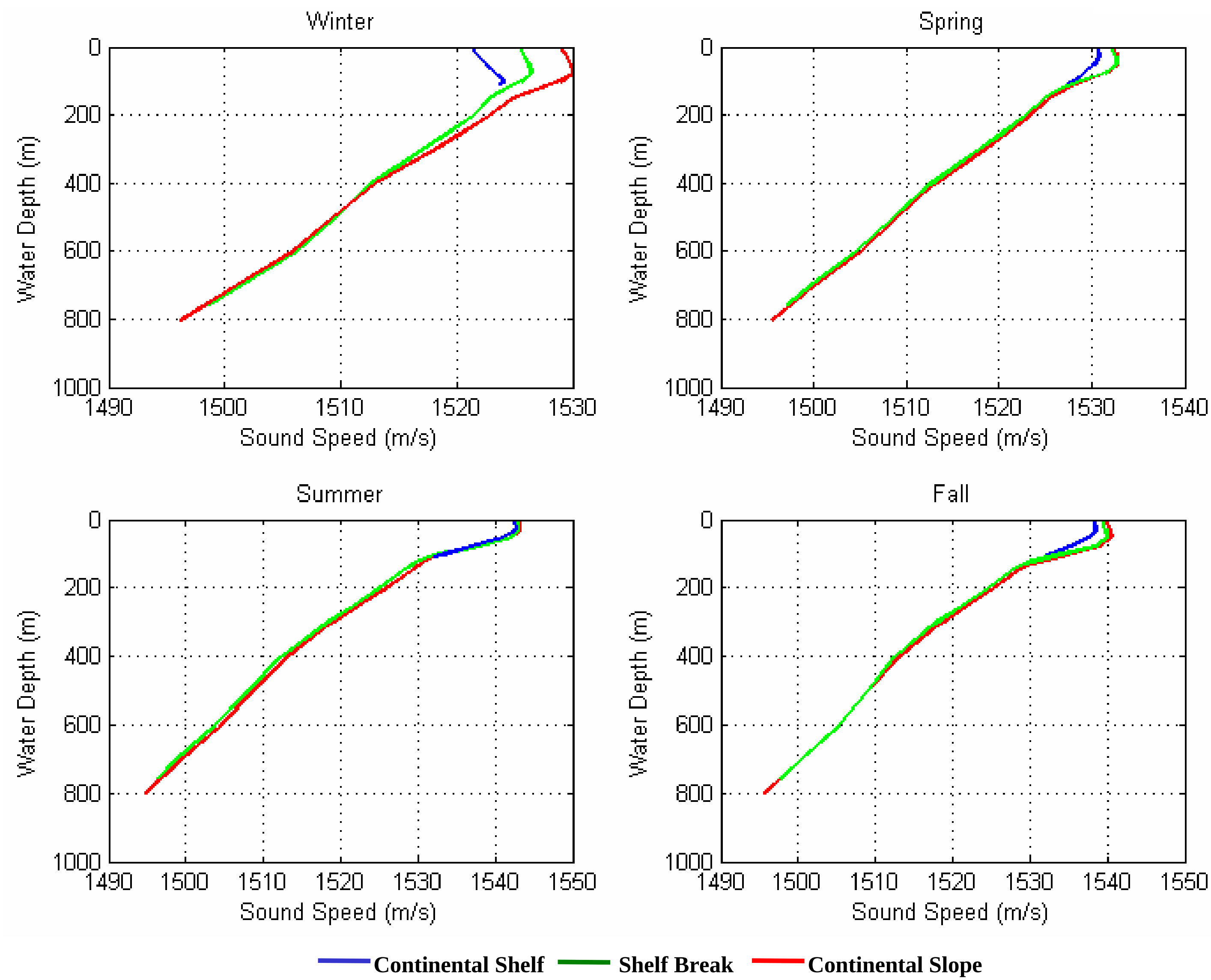

Figure 5-7. SSPs for Jacksonville Analysis

5.3.5 Sediment Characteristics and Bottom Loss model

For Onslow Bay, the Navy standard bottom loss reflection coefficient model for <10 kHz is the Low-Frequency Bottom-Loss (LFBLTAB) model. The model requires a detailed description of the physical characteristics of the bottom sediment such as bottom sound speed, bottom depth, two-way travel time to the geological basement, water to bottom sound speed ratio, thin layer thickness, and thin layer sediment density. A more detailed list of the required inputs is documented by Weinberg et al. (2001). The Naval Research Laboratory has published several technical documents describing the geo-acoustic properties of Long Bay (Gomes et al., 2000a and 2000b; Erksine, 1998). The sediment characteristics for the three regimes described within the Long Bay area (immediately south of Onslow Bay) were extrapolated to Onslow Bay using available side-scan and sub-bottom data to classify the area within each regime. The output of the LFBLTAB model is a table of the bottom-loss reflection coefficient as a function of grazing angle.

One source was modeled that operates at a frequency greater than 10 kHz. For this source, the Applied Physics Laboratory, University of Washington (APL/UW) bottom-loss model was used. The Marine Geophysical Survey (MGS) bottom-loss data are required for this model. The respective bottom types were chosen to correspond to the sediment type found in the training area.

For the Wallops Island site, data on bottom type were obtained from a Woods Hole Oceanographic report (Hathaway, 1977). These data provided an adequate picture of bottom types, but they provided too few input parameters to use in the CASS GeoAcoustic Module. Results at the Wallops Island site delineated the site into the sandy bottom Continental Shelf regime and the muddy sediment bottom Continental Slope regime.

The bottom type information for the Jacksonville site was obtained from the DON Marine Resource Assessment (2002c).

In the GRAB propagation model, the bottom can be characterized in several ways. Because of the large spread in acoustic frequencies, four standard models were used. Three of these models are applicable for mid-frequencies (3 to 8 kHz): (1) the MGS bottom loss data for mid-frequencies, (2) Wide-Band Able, and (3) the Rayleigh model (which does not need a bottom province or MGS application). The APL/UW bottom loss model was used for high frequencies. The respective bottom type for each model was chosen to correspond to the sediment type found in the training area and is listed in tables 5-7 and 5-8.

Table 5-7. Bottom Types for Onslow Bay and Wallops Island

Onslow Bay			Wallops Island		
Depth Region (m)	Sediment Type[1]	APL/UW[2] TR 9407 HF Grain Index	Depth Region (m)	Sediment Type*	APL/UW[2] TR 9407 HF Grain Index
20-60	Hard sand	1.5	20-60	Coarse sand	1.5
60-200	Transition hard sand to mud	4.0	60-200	Transition coarse sand to fine sand	3.5
200-2000	Sediment (mud)	4.0	200-1000	Transition fine sand to green mud	5
			1000-2000	Green mud	5
References: [1]Hathaway (1977); [2]APL/UW.					

Table 5-8. Bottom Types for Jacksonville

Depth Region (m)	Sediment Type[1]	APL/UW[2] TR 9407 HF Grain Index
20-60	Coarse sand	0.5
60-200	Sand/Silt/Clay	5.5
200-800	Sand/Silt/Clay	5.5
References: [1]Hathaway (1977); [2]APL/UW (1994).		

5.4 PROPAGATION MODEL CONSIDERATIONS

The total energy flux for all pings will exceed the level of the loudest ping when multiple pings are received at any point. To calculate the accumulation of energy from multiple pings, the acoustic propagation analysis must be done up to a distance ensuring that the potential for cumulative energy exceeding the criteria is assessed. The extent to which receive levels need to be accumulated below the threshold depends on the source operational characteristics including: source level, source movement, ping duration, and ping repetition rate. Based on an examination of these parameters, propagation losses were calculated to a range of 1000 m around each point of a moving source and stationary source. The CASS model also requires definition of the water depth and distance intervals used in the analysis. For the propagation analysis, depth intervals of 2 m and distance intervals of 5 m were used.

Each of the proposed USWTR sites has range-varying bathymetry and sediment types in addition to the seasonal SSP changes—all of which present a challenge to model effectively and to model within realistic time constraints. One feature of all sites is the parallel nature of the bathymetric contours, which allows the number of propagation bearing angles from each source to be reduced because of left/right symmetry. The bearing angles modeled are 0°, 45°, 90°, 135°, and 180°. The results of 45°, 90°, and 135° are reused for 315°, 270°, and 225° respectively. The symmetry is shown in figure 5-8.

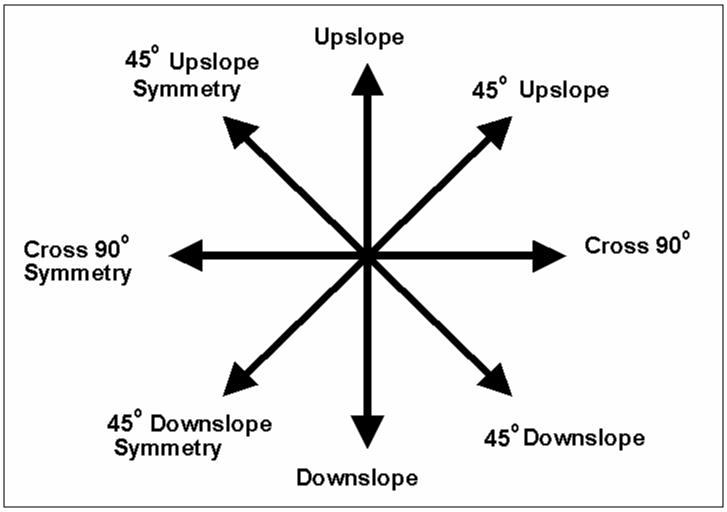

Figure 5-8. Symmetry for Propagation Analysis

Examination of the variability of propagation loss results at the proposed Onslow Bay, Wallops Island, and Jacksonville SWTR sites was conducted. Propagation losses vary with the surface and bottom interaction, which in turn are a function of the water depth. An illustration of this effect is shown in an extended distance propagation analysis (figure 5-9), where distinct points of surface and bottom reflections are visible. These are often also points where energy from multiple ray paths is present. As a result of this examination, the number of water depths modeled was reduced to three. This finite number of depth regimes adequately represents propagation variability while limiting the volume of the modeling effort. Source positions for propagation modeling were limited to three depth regimes defined as

1. 20 to 60 m—Continental Shelf,
2. 60 to 200 m—Shelf Break,
3. 200 to 2000 m—Continental Slope.

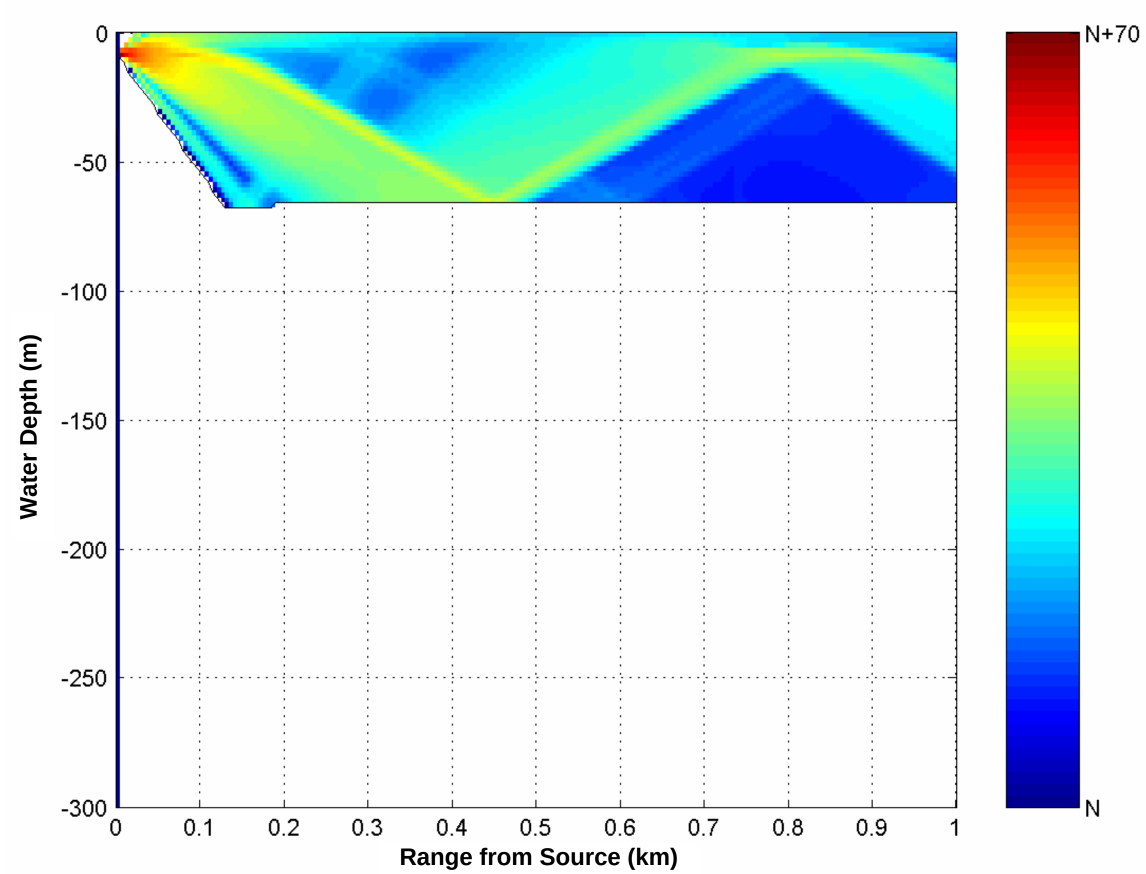

Figure 5-9. Sample Propagation Analysis Illustrating Boundary Interactions

The range area maps (figures 5-10, 5-11, and 5-12) show the selected source positions for the propagation modeling. To use these points in the acoustic propagation model, they were translated into x-y coordinates to be consistent with GRAB input parameters. Approximately 70%, 93% and 73% of the final analysis area is at a depth less than 200 m for Onslow Bay, Wallops Island, and Jacksonville, respectively. This factor is used in the take estimation.

Even with the reduction of angles and source positions modeled, hundreds of propagation runs were conducted to represent the multiple source types, source depths, source frequencies, seasonal changes, depth regimes, and operating modes.

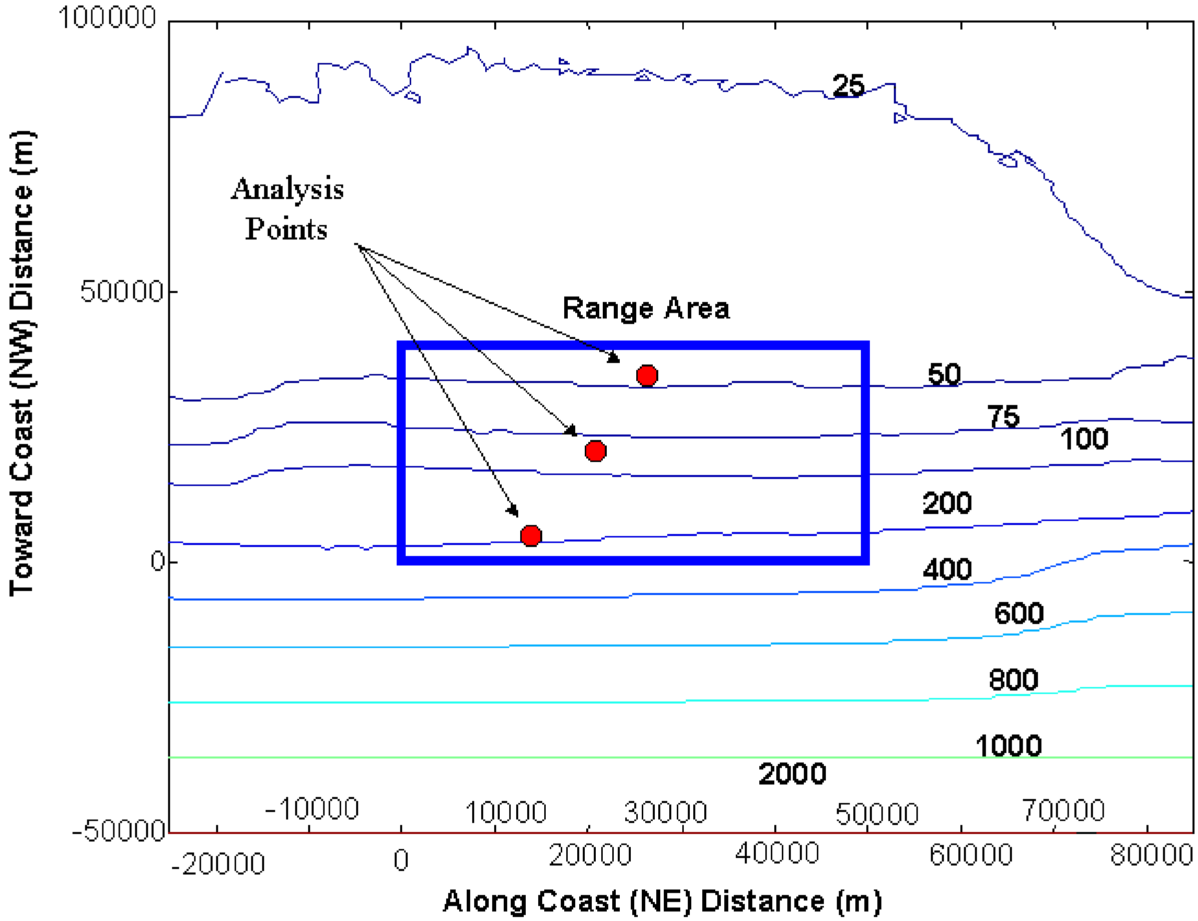

Figure 5-10. Onslow Bay Selected Source Positions for Propagation Modeling

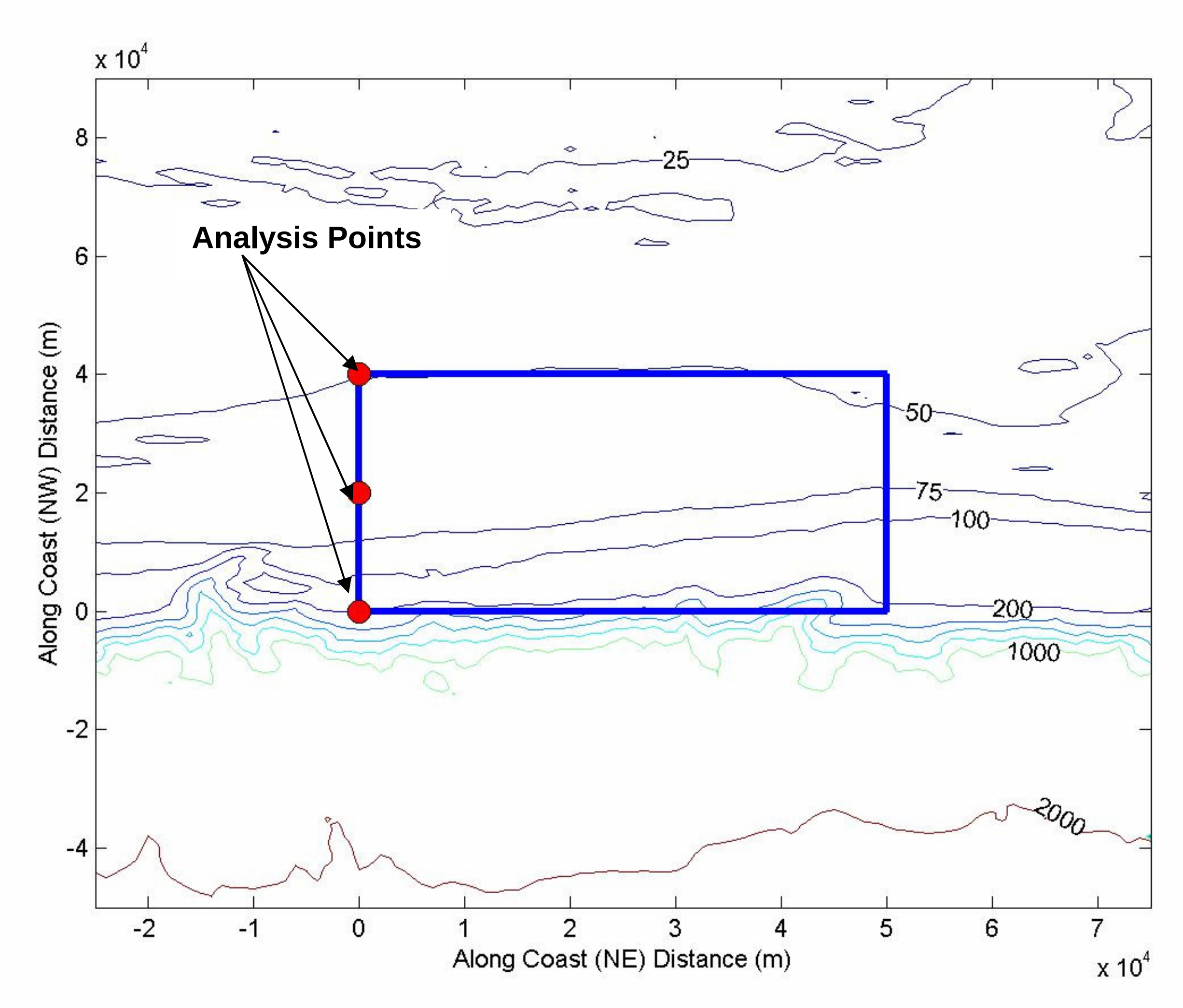

Figure 5-11. Wallops Island- Selected Source Positions for Propagation Modeling

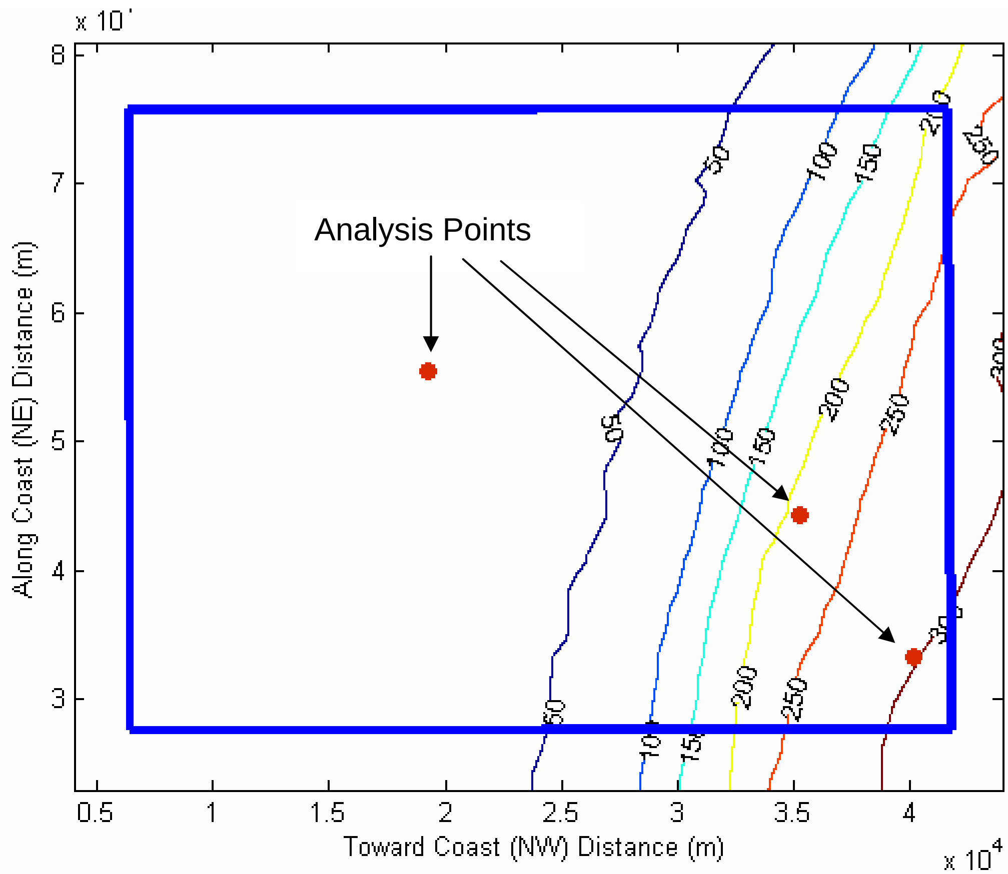

Figure 5-12. Jacksonville Selected Source Positions for Propagation Modeling

6. TAKE CALCULATIONS

This section describes the method by which the estimated take number is calculated for marine mammals that would be subjected to acoustic sources above the acceptable marine mammal acoustic effect definition. This analysis combines the input data on marine mammal distribution and density from section 2, the Level A and Level B harassment thresholds summarized in section 3, the Navy source and scenario definitions in section 4, and the acoustic propagation analysis described in section 5.

6.1 ASSUMPTIONS

Inherent to the take prediction model is the consideration of mammal distribution, hearing, and diving behavior. In this analysis, no attempt was made to predict animal behavior in response to sound in the water or their location relative to the point where the source initiates operation. It was assumed that mammals have omnidirectional hearing. This approach was used because there was no basis provided for the mammal responses over time to the sources. Diving behavior of the mammals was not modeled, but was a factor in calculating population densities when appropriate (Hain and Kenney, 2001). It was assumed that mammals were exposed to the maximum receive levels calculated for the horizontal distance to the source at any water depth for that distance. Lastly, for each depth regime, animals were distributed with a static, uniform density across the range area. The mammal data do not provide a basis for reflecting greater resolution in their location and prediction of animal movements, which thereby result in changes in density distributions that cannot be substantiated.

6.2 ACOUSTIC FOOTPRINT CALCULATION

For each CASS propagation analysis run, an acoustic footprint was calculated. This set of footprints delineates propagation variation versus source operating mode, season, and operating depth at each analysis point.

The first step is to convert the CASS propagation loss versus range and depth for each bearing angle to a single maximum receive level versus range curve, as shown in figure 6-1. This is accomplished by filtering the minimum propagation loss at each range increment and adding the source's output sound pressure level (SPL). (The actual curves are classified due to the inclusion of source level data.)

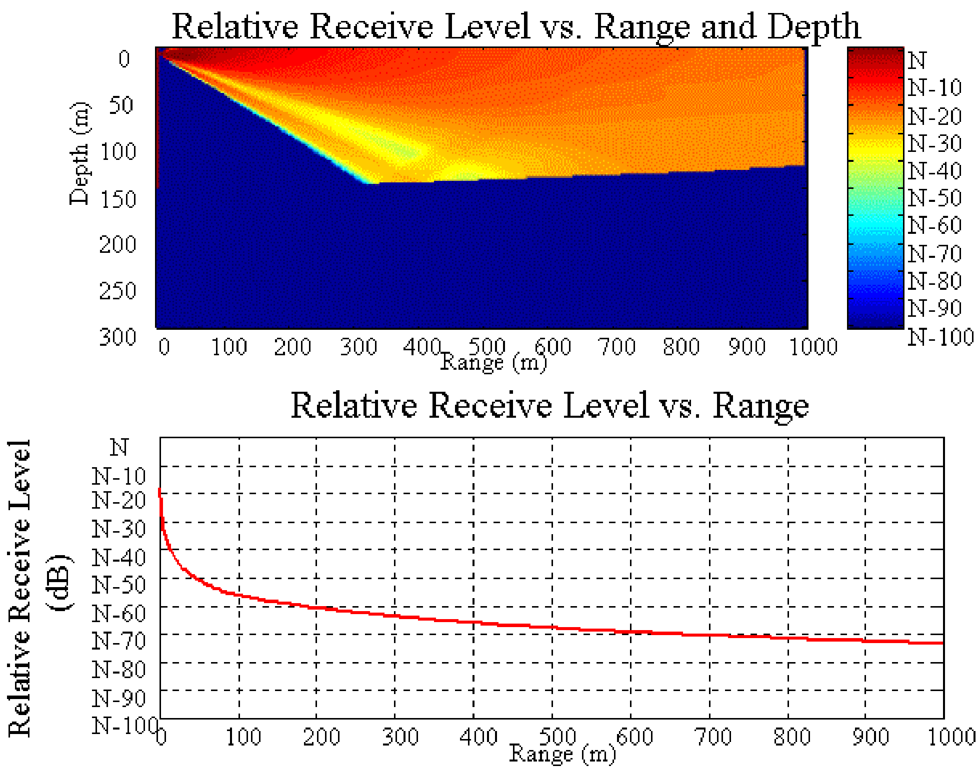

Figure 6-1. CASS Propagation Output and Corresponding Maximum Receive Level vs Range Curve

For omnidirectional sources, the acoustic footprint is generated by translating the maximum receive level versus range along the eight bearing spokes into a continuous two-dimensional array. For each bearing angle, the maximum receive level curve is used to populate all angles around the source ±22.5°. This results in a continuous 360° characterization of the receive level from the source. An illustration of this is shown in figure 6-2. The resulting sectors are each 45° wide. A single receive level is used at a fixed range from the source within the sector. It should be noted that the slope references (i.e., upslope, downslope, cross) refer to the direction of sound propagation that was modeled, not source movement.

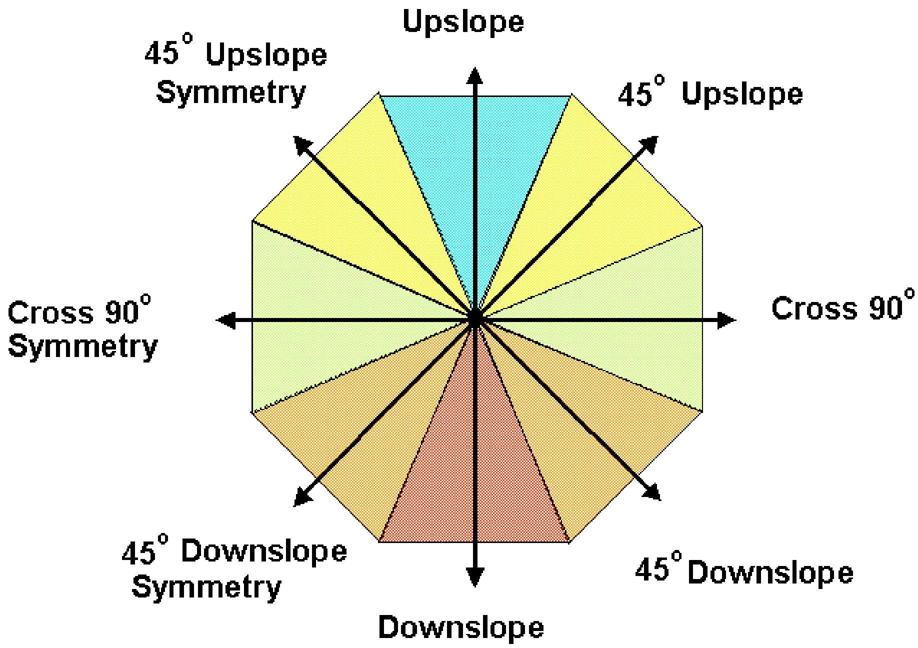

Figure 6-2. Acoustic Footprint Calculation from CASS Propagation Curves Along Modeled Bearing Angles

Two example acoustic footprints are shown in figure 6-3. The receive level is color coded with red indicating the loudest and blue indicating the weakest signals. The Continental Slope example highlights greater variability in received level versus the propagation direction.

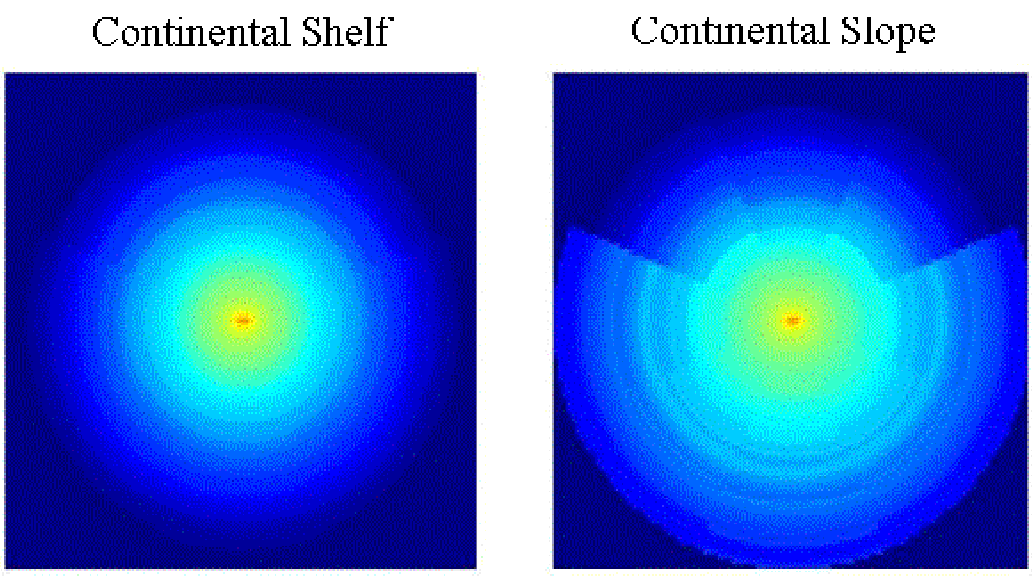

Figure 6-3. Examples of Acoustic Footprints for the Continental Shelf (Left) and the Continental Slope (Right) Depth Regimes

For stationary directional sources, the acoustic footprint is generated only for sectors that lie within the source's horizontal beamwidth. For moving directional sources, the beamwidth was centered with the main response axis oriented in the direction of movement, i.e., cross, upslope, or downslope. An example of a cross-slope footprint is shown in figure 6-4. For directional stationary sources, variation in the footprint orientation was captured by calculating the three footprints facing upslope, downslope and cross slope. In all cases, the acoustic footprint size is matched to the CASS propagation distance of 1000 m, resulting in a footprint of 1000 m in radius.

The distance resolution in the acoustic footprint (25 m) equals five times that of the CASS propagation analysis. Thus, each data point within the acoustic footprint represents an area 25 m^2. The maximum receive level of the five points within the 25-m interval is selected as the single data point for the acoustic footprint. For example, the minimum loss for 105, 110, 115, 120, and 125 m would be used for the single footprint value covering 100 to 125 m. An analysis was conducted to determine the maximum decimation in this step that could be implemented without compromising the accuracy of the results. The positive benefit of this step is reduction in the number of receive cells that must be modeled for the range area reducing processing time by an order of magnitude.

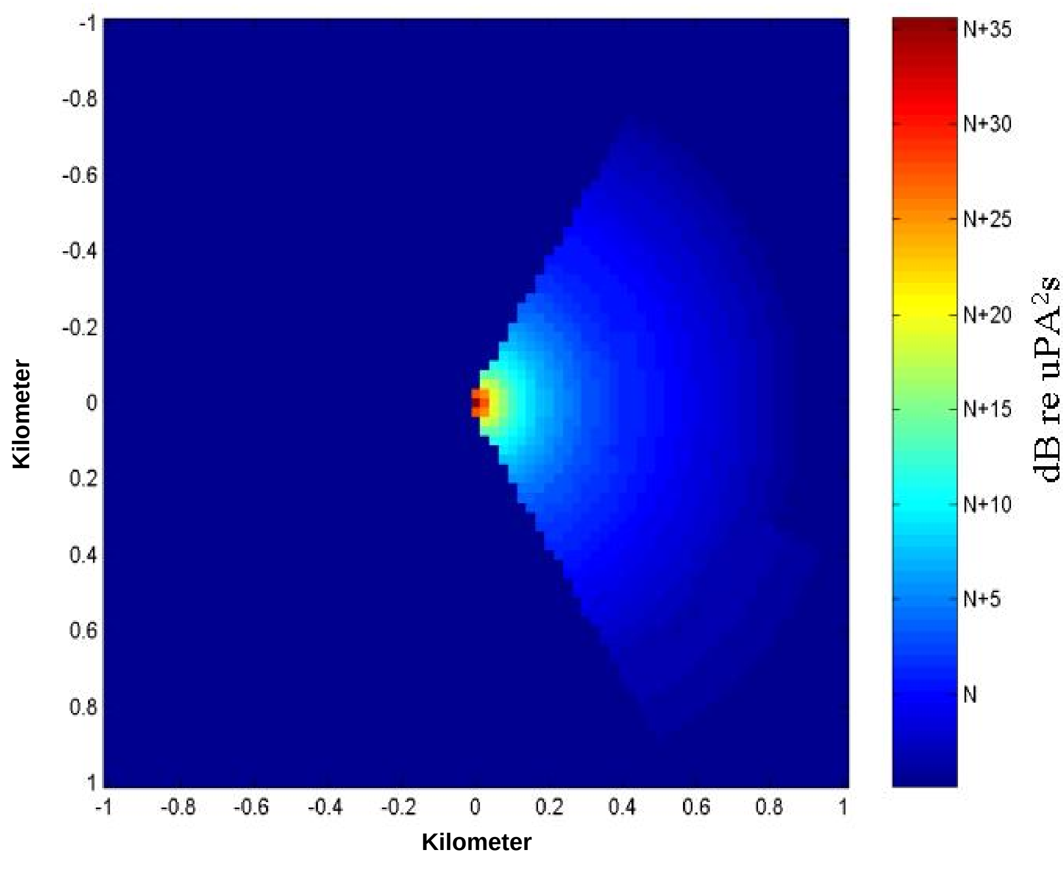

Figure 6-4. Applying a Beam Pattern for a Directional Acoustic Footprint

6.3 MODELED SOURCE PATHS AND LOCATIONS

The USWTR exercise participants are allowed to maneuver without restriction during a training exercise. To model the variable movement of exercise participants on the range, five representative moving source paths and three stationary source positions were chosen, as shown in figure 6-5. The five tracks correspond to one cross-slope track within each depth regime combined with one upslope and downslope track. No participant can move over the entire range area in a single exercise, because of its limited duration (i.e., 6 hours). These representative paths and positions are used to find the area above the Level B harassment thresholds.

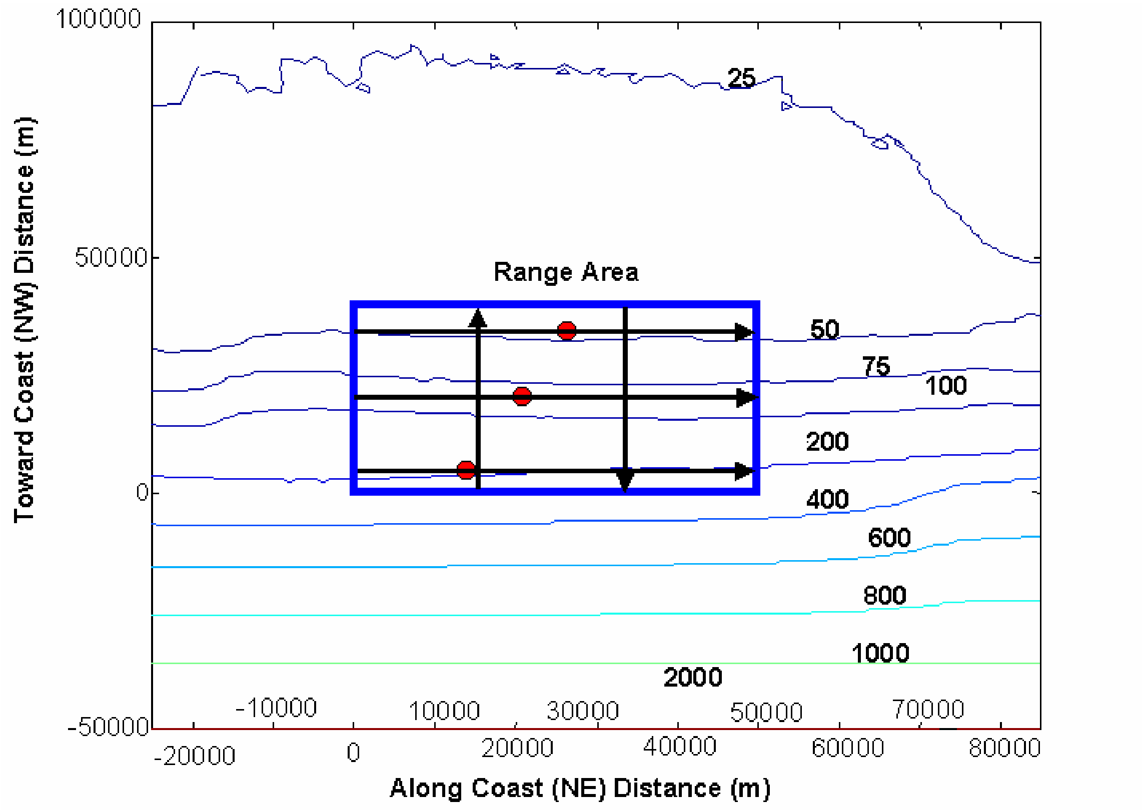

Figure 6-5. Ship Tracks and Stationary Points Used in Onslow Bay Analysis

Omnidirectional, stationary sources employ a single acoustic footprint for the analysis points in each depth regime (three total footprints). For directional, stationary sources, three acoustic footprints are used in each depth regime: upslope, downslope and cross-slope (nine total footprints). The results from these footprints are averaged to produce the take rate.

For moving sources, their acoustic output is modeled along the five vessel tracks. These tracks include upslope, downslope, and cross-slope movement to capture the beam pattern effects versus direction of travel. A primary consideration in selecting the paths is to ensure that the mammal populations distributed within the analysis area intersect with one or more of the identified paths. For the USWTR, this means that acoustic paths must encompass both areas above and below 91.4-m depth, as this delineation is made in the mammal distribution data.

For moving sources, the acoustic footprint will change as a new depth regime is entered while moving along the source path. Moving sources also use the acoustic footprint beam pattern that reflects the direction of travel, i.e., upslope, downslope, or cross-slope.

6.4 RECEIVE CELL LEVEL CALCULATIONS

The receive levels are calculated for each data cell for the entire analysis area. The receive cells extend to 1 km beyond the range's boundary, as sound is not restricted from propagating outside of the instrumented tracking area. For the source paths and stationary positions, the receive level is recorded for each modeled ping in all cells overlapped by the acoustic footprint. Any receive cell not overlapped by the acoustic footprint records no received ping.

To perform the receive cell level calculation for a moving source, it is positioned at one end of the path being analyzed. The receive levels are determined by overlaying the acoustic footprint on the source point and storing the footprint's values in all overlapped receive cells. The time of transmission for that ping is also recorded. This is shown conceptually in figure 6-6. The source point is then incremented along the source path to the next point and the process is repeated. The distance moved along the path is calculated from the vessel speed and the time interval between pings. For example, if a ship is moving at a speed of 18.5 km/hr (10 knots) and pinging at an interval of 30 seconds, the next analysis point would be 154.2 m further along the path. Incrementing the source point continues until the full path has been completed. Receive cell data are generated on a per source, season, and track basis.

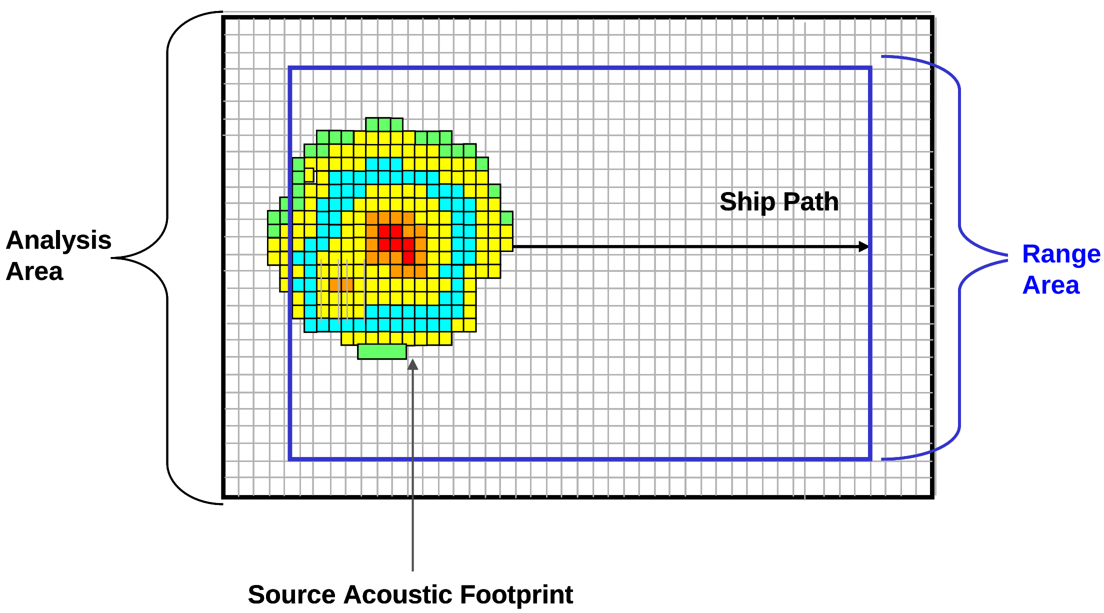

Figure 6-6. Modeling a Source's Movement Along a Track

An example of the receive level of each ping versus time for a single receive cell is shown in figure 6-7. This example represents a point where a directional source's track passed directly over the cell. This produces the upslope in the received level, as the source moves towards the cell. After passing the cell, the receive level is zero, because the cell is out of the horizontal beamwidth of the source.

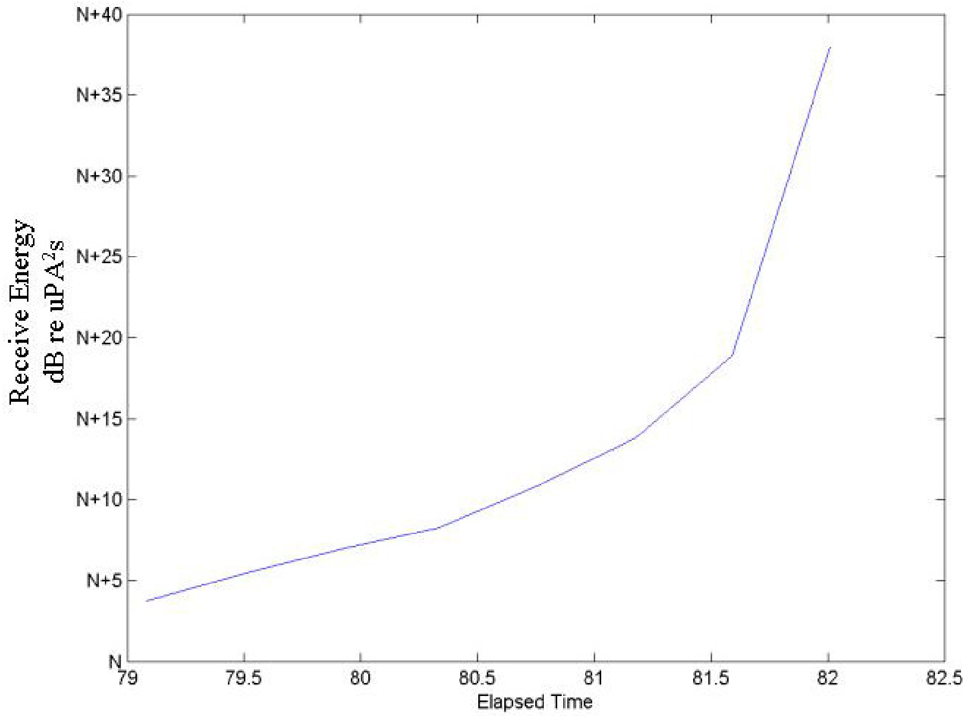

Figure 6-7. Example of the Receive Level vs Time for One Geographic Cell

For stationary sources, the process is simpler. The acoustic footprints are positioned at the fixed transmission points and the receive levels recorded in the cells. If multiple pings originate from a single point, such as with the dipping sonar, the repetition rate and number of pings are modeled and the levels recorded. For stationary sources that do not have an omnidirectional beam pattern, the responses for three directions (upslope, downslope and cross-slope) are calculated and averaged in the analysis.

6.5 TOTAL ENERGY FLUX CALCULATIONS

The total energy flux calculation determines the level received at each geographic cell on the range area from each ping signal and stores the data in a four dimensional matrix (x- and y-cell position, ping transmission time, and received level for each ping). Calculating each cell's receive levels combines the acoustic footprint with source speed and the operational duty cycle characteristics, such as ping repetition rate. The matrix is uniquely calculated for each source operational mode, depth, and season. The two surface sonars each have two modes, i.e., search and target, while the remaining sources have a single operational mode. The sources with multiple operational depths are the ALFS, torpedo, and submarine sonars. Source paths (defined above in section 6.3) allow the model to characterize the variations in sound propagation over the range site (see section 6.3).

As noted above, this analysis stores time of emission and received level data at each geographic cell for the range for each ping. Each cell corresponds to specific region of the range area, e.g., a 25-m x 25-m square. The cell size is adjusted to be five times larger than the resolution in the propagation analysis. For the USWTR modeling the total analysis area consisted of 201 by 181 cells, or a total of 36,381 cells.

The acoustic energy (AE) map is a display of the total energy flux accumulated from a modeled source, taking into account the intensity, duration and number of received pings. The total AE is calculated from the AE matrix data for each cell. The data for received pings within each grid cell are converted to a total energy flux value for that cell. An example of an AE map is shown in figure 6-8. Areas along the path are those at the highest total energy. The energy decays as the distance from the vessel track increases. The acoustic footprint is adjusted as the source moves through the depth regimes. In this example, the transmission point (red cell) for each individual ping can be observed. The track also shows the effect of the source's horizontal beamwidth.

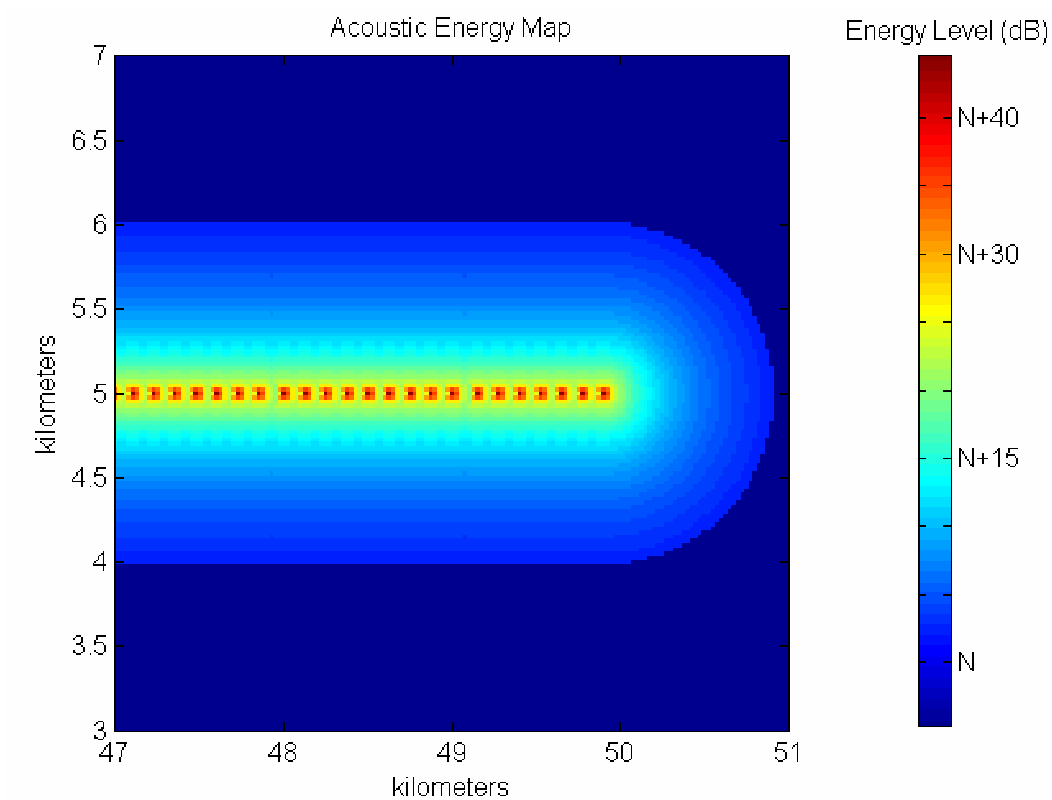

Figure 6-8. Example of a Portion of an AE Map

6.6 MARINE MAMMAL THRESHOLD ANALYSIS AND TAKE RATE CALCULATION

Once the total AE is calculated for a given source and source path, determination can be made for each individual cell as to whether the harassment Level B thresholds have been exceeded. The determination is a comparison of the total energy flux and Level B threshold. The comparison records the number of cells above the threshold for the regions of the range greater and less than a 91.4-m water depth. This distinction is required to match the mammal density breakdown by water depth.

The cell count is converted to a total area for which the threshold has been exceeded based on the modeled cell size. For example, if each cell is 25 m x 25 m and the number of cells above the threshold was 500, the total harassment area would be 0.3125 km^2. These resulting areas are exported to the spreadsheet analysis that generates the estimation of the number of takes.

6.6.1 Spreadsheet Analysis

The spreadsheet analysis uses a series of steps to produce the final estimate of takes:

1. Harassment areas per source use are converted into take rates.
2. Take rates are combined with mammal density to generate a species take rate.
3. The operational scenario data for use of each source is applied to the species take rates to produce the take estimates for each mammal.
4. Summary totals for Level A and Level B take estimates are generated.

6.6.2 Take Rate Calculation

6.6.2.1 Take Rate Calculation for Moving Sources. The take rate for each source is based on how its operational use has been described. Table 6-1 shows the take rate* definitions. Moving sources (surface sonars and the dipping sonar) have take rates expressed in takes/km. The AN/BQQ-5 submarine sonar defines the rate as takes/ping. The torpedo sonar uses a definition of takes/use, i.e., takes are estimated for each torpedo firing. Unique take rate calculations occur for each combination of each source, season, and operational mode.

Table 6-1. Take Rate Definitions for Each Source

Source	Take Rate Definition
AN/SQS-53C Surface Sonar	Takes/km of Vessel Movement
AN/SQS-56 Surface Sonar	Takes/km of Vessel Movement
AN/BQQ-5 Submarine Sonar	Takes/Ping
Torpedo Sonar	Takes/Use
Helo Dipping Sonar	Takes/km of Helo Movement

* The term *Take Rate* is a misnomer. These data actually represent the rate that the area above the harassment thresholds is generated by the source's operation.

An example of a moving source take rate calculation is shown in table 6-2 for the Onslow Bay site. The Level A and Level B take rates are handled identically at this point, although the harassment areas are derived from separate analysis. The area for Level A is subtracted from that for Level B to prevent double counting the area in take estimates. The take rates at this point are a normalized value for a mammal density of 1 animal/1000 km^2. The total harassment area for all source paths is divided by total track length to produce a factor of harassment area per kilometer, which is called the take/km. Since the mammal densities for all three candidate sites are reported seasonally for depths greater and less than 91.4 m, a separate rate is maintained for the areas above and below a 91.4-m water depth, but each is derived from the same five ship tracks.

Table 6-2. Take Rate Calculation for the AN/SQS-53C Search Mode in Autumn for Onslow Bay

Bathymetric Interval	Area Above Level A Threshold (km^2)	Area Above Level B Threshold (km^2)	Total Source Path Length (km)	Level A Take Rates (take/km)	Level B Take Rate (take/km)
< 91.4 m	0.20659	241.71172	230	8.9822E-04	1.05
> 91.4 m	0.15102	108.86845	230	6.5661E-04	0.4727

6.6.2.2 Take Rates Calculations for Stationary Sources. For stationary sources, the process is essentially the same as for moving sources, but the analysis calculates takes per use rather than by distance. The average harassment area is determined on a per use basis. If the source is horizontally directional, the take rate is an average based on the harassment area for the three directional orientations at each source position and depth modeled. An example of the results for the submarine sonar is provided in table 6-3. In this case, the submarine sonar take rates are based on an average of 12 pings: each of the three positions (four depth combinations) with each directional orientation (upslope, downslope and cross-slope). These values are based on the Onslow Bay site.

Table 6-3. Take Rates for the AN/BQQ-5 Sonar in Autumn for Onslow Bay

Stationary Position	Depth (m)	Area Above Level A Threshold < 91.4 m (km^2)	Area Above Level A Threshold > 91.4 m (km^2)	Area Above Level B Threshold < 91.4 m (km^2)	Area Above Level B Threshold > 91.4 m (km^2)
1	27.4	1.1921E-04	8.7145E-05	0.04164	0.03044
2	27.4	1.1921E-04	8.7145E-05	0.06475	0.04733
3	27.4	1.1921E-04	8.7145E-05	0.07342	0.05367
1	122		8.7145E-05		0.17063
Take Rate		1.1921E-04	8.7145E-05	0.059818	0.07543
Note that the area attributed to Level A is subtracted from Level B to avoid including that area twice.					

6.6.2.3 Species Take Rate Calculation. With the take rate for each source use case (the combination of season, site, depth, mode, and effect threshold) the species take rates are calculated. Recall that the take rate is an expression of harassment area (km^2). Since the mammal density is expressed as mammals per 1000 km^2, the Take Rate needs to be divided by 1000 before applied to the density. The product of the take rate and the species population density is the species take rate. For each season, the product is calculated per depth regime and summed to produce the seasonal species take rate. An example of the species take rate calculation is shown in table 6-4 for the AN/SQS-53C in autumn using the search mode and the Bottlenose Dolphin. The results are applied to the total use by the source to calculate the take estimate.

Table 6-4. Species Take Rate Calculation Example for Onslow Bay

Bathymetric Interval	Level A Take Rate (take/km)	Level B Takes Rate (take/km)	Bottlenose Dolphin Density (No. per 1000 km^2)	Species Level A Take Rate (Species Take/km)	Species Level B Take Rate (Species Take/km)
< 91.4 m	8.9822E-04	1.05	19.98	4.91E-05	0.0434
> 91.4 m	6.5661E-04	0.47268	47.5		

6.6.2.4 Take Estimate Calculations. Table 6-5 details the information used in the final spreadsheet calculations. This example is based on the AN/SQS-53C surface sonar and Bottlenose Dolphins in the autumn season during scenario 2 for Onslow Bay. The species take rate is multiplied by the total use of the source for the given scenario and season. For a moving source, the total distance spent pinging is required since the species take rate is expressed in take per kilometer (take/km). Thus, the calculation incorporates the source speed, exercise duration, operational duty cycles, and occurrences of each scenario by season as characterized in section 4. As described in section 2.1.3, accounting for the unidentified population of dolphins and *stenella* increases the final take estimate by 32.2%.

Table 6-5. Bottlenose Dolphin Level B Take Estimate for AN/SQS-53C for Onslow Bay Operation in Scenario 2 During Autumn

Factor	Value
Yearly Scenario Occurrences	30
Scenario Duration	6 hours
No. of Surface Sonar Platforms in the Scenario	1
No. of Total Source 53C Platforms Used (70% - 53C; 30% 56 X Surface Sonar)	21
No. of 53C Sonar Platforms Used in Autumn	5.25
Operational Duty Cycle (split with Helos)	50%
Ship Speed (km/hr)	18.52
Search Mode Operational Percentage (split with track mode)	67%
Applicable Species Take Rate	0.0434
AN/SQS-53C Search Mode Exercise Takes	8.48
AN/SQS-53C Search Mode Exercise Takes, Unidentified Species Included	11.21

7. RESULTS

The following tables (tables 7-1 through 7-9) summarize the number of estimated takes by sonar source, scenario, and mammal population for the Onslow Bay, Wallops Island, and Jacksonville sites. All take estimates reflect adjusted totals to account for unidentified species.

7.1 ONSLOW BAY TAKE ESTIMATE SUMMARIES

Table 7-1. Onslow Bay Annual Take Estimate Summary by Source

Source	EL ≥ 215 dB	215 > EL ≥ 195 dB	195 dB > EL ≥ 190 dB
AN/SQS-56	0.05	12.38	16.74
AN/SQS-53C	0.92	324.41	610.73
Submarine	0.01	1.44	5.26
Mk-48	0.01	3.35	16.15
ALFS	0.02	2.64	5.79

Table 7-2. Onslow Bay Take Estimate Summary by Scenario

Scenario	EL ≥ 215 dB	215 > EL ≥ 195 dB	195 dB > EL ≥ 190 dB
1	0.01	2.07	4.54
2	0.55	188.34	354.67
3	0.01	3.06	13.07
4	0.44	150.75	282.39

Table 7-3. Onslow Bay Annual Take Estimate Summary by Marine Mammal Population

Mammal	EL ≥ 215 dB	215 > EL ≥ 195 dB	195 dB > EL ≥ 190 dB
Bottlenose Dolphin	0.17	55.21	109.69
Pilot Whales	0.01	2.97	5.32
Saddleback Dolphin	0.13	37.66	66.54
Grampus	0.02	5.55	10.01
All Beaked Whales	0.04	10.31	18.63
Humpback Whale	0.01	2.54	4.63
Sperm Whales	0.01	2.90	5.37
Spotted Dolphin	0.62	226.43	433.37
Clymene Dolphin	0.00	0.47	0.82
Pygmy Dwarf Sperm Whale	0.00	0.06	0.12
Rough Toothed Dolphin	0.00	0.10	0.17
Note: Take estimates reflect adjusted totals to account for unidentified species.			

7.2 WALLOPS ISLAND TAKE ESTIMATE SUMMARIES

Table 7-4. Wallops Island Annual Take Estimate Summary by Source

Source	EL ≥215 dB	215 > EL ≥195 dB	195 dB > EL ≥190 dB
AN/SQS-56	0.07	14.54	29.88
AN/SQS-53C	1.20	420.34	687.97
Submarine	0.01	2.13	5.77
Mk-48	0.02	6.06	28.07
ALFS	0.03	3.50	7.24

Table 7-5. Wallops Island Take Estimate Summary by Scenario

Scenario	EL ≥215 dB	215 > EL ≥195 dB	195 dB > EL ≥190 dB
1	0.02	2.75	5.67
2	0.72	243.99	408.75
3	0.02	5.05	19.32
4	0.57	194.79	325.18

Table 7-6. Wallops Island Annual Take Estimate Summary by Marine Mammal Population

Mammal	EL ≥215 dB	215 > EL ≥195 dB	195 dB > EL ≥190 dB
Bottlenose Dolphin	0.16	64.00	96.27
Pilot Whales	0.09	33.30	51.35
Saddleback Dolphin	0.66	210.37	375.22
Risso's	0.11	37.68	63.19
Beaked Whales	0.00	1.29	2.17
North Atlantic Right Whale (E)	0.00	0.22	0.29
Striped Dolphin	0.04	10.15	21.78
Spotted Dolphin	0.19	62.93	108.96
Sperm (E)	0.02	5.51	10.28
Fin Whale (E)	0.03	12.27	18.24
Humpback Whale (E)	0.00	0.41	0.86
Sei Whale (E)	0.00	0.39	0.77
Atlantic White-Sided Dolphin	0.00	0.24	0.55
Minke Whale	0.00	0.99	1.75
Pygmy Dwarf Sperm Whale	0.00	0.25	0.40
Killer Whale	0.00	0.01	0.01
False Killer Whale	0.00	0.08	0.12
Rough-Toothed Dolphin	0.00	0.08	0.12
Spinner Dolphin	0.00	0.15	0.28
Harbor Porpoise	0.01	6.27	6.29
Note: Take estimates reflect adjusted totals to account for unidentified species. (E) = Endangered species.			

7.3 JACKSONVILLE TAKE ESTIMATE SUMMARIES

Table 7-7. Jacksonville Annual Take Estimate Summary by Source

Source	EL ≥ 215 dB	215 > EL ≥ 195 dB	195 dB > EL ≥ 190 dB
56	0.04	4.13	7.45
53C	0.69	172.36	310.43
SUB	0.00	0.64	1.63
MK-48	0.00	2.62	5.51
ALFS	0.02	18.15	38.32

Table 7-8. Jacksonville Take Estimate Summary by Scenario

Scenario	EL ≥ 215 dB	215 > EL ≥ 195 dB	195 dB > EL ≥ 190 dB
1	0.01	14.23	30.04
2	0.41	101.07	182.97
3	0.01	1.91	4.31
4	0.33	80.69	146.02

Table 7-9. Jacksonville Take Estimate Summary by Marine Mammal Population

Mammal	EL ≥ 215 dB	215 > EL ≥ 195 dB	195 dB > EL ≥ 190 dB
Bottlenose Dolphin	0.14	38.47	69.63
Pilot Whale	0.00	0.62	1.30
Saddleback Dolphin	0.03	14.58	31.70
Grampus	0.01	7.06	14.86
All Beaked Whales	0.02	13.24	27.25
Humpback Whale (E)	0.00	0.13	0.23
North Atlantic Right Whale (E)	0.00	0.16	0.28
Spotted Dolphin	0.54	119.34	209.29
Pgymy Dwarf Sperm Whales	0.00	0.18	0.39
Rough Toothed Dolphin	0.00	0.01	0.01
Minke Whales	0.01	3.16	6.29
False Killer Whale	0.00	0.01	0.03
Spinner Dolphin	0.00	0.95	2.07
(E) = Endangered species.			

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